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ABSTRACT

Included are instructional materials designed for use with disadvantaged students who have a limited reading ability and poor command of English. The guide is the first volume of a two volume, one year program in physical science, and contains these five units and activities: First Class Levers, six activities; Inclined Plane, six activities; The Pulley, three activities; Friction, five activities; and Heat, nine activities. A formal textbook is not used in this program, and the learning process relies on class discussion supported by audiovisual materials and small group laboratory activities. Each lesson has a suggested format for teachers to follow in directing activities, with suggested teacher comments. Following each teacher section is the printed material for student use, which generally has a list of required equipment for small group activities, introduction and procedures, and fill-in questions relating to the completed activity. The volume begins with extensive "guidelines for creating an appropriate classroom environment for educationally disadvantaged youth." The appendix includes an equipment list, and for each activity there is a full page diagram for making overhead projector transparencies. (PR)

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The DISCUS project has developed a course of study in science for the junior high grades (7-9). The material for each grade level has been bound into two manuals.

GRADE 7	BIOLOGICAL SCIENCE
GRADE 8	PHYSICAL SCIENCE
GRADE 9	EARTH SCIENCE

Your comments concerning these materials will be appreciated. For further information, contact the project director.

Revised
9-1-69

DISCUS EIGHTH GRADE PHYSICAL SCIENCE

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I

GUIDELINES FOR CREATING AN APPROPRIATE CLASSROOM ENVIRONMENT FOR EDUCATIONALLY DISADVANTAGED YOUTH APPLIED IN AND SUPPORTED BY THE PROJECT

1. Assumptions Made Regarding Educationally Disadvantaged Youth

    a. Human ability is to a large extent a social product. It depends upon the opportunities in the environment for meaningful and varied experiences. In many areas it does not develop unless recognized and encouraged by society.

    b. Educationally deprived children have had a narrow range of experiences in a limited environment, hence have a lack of confidence in themselves in a classroom situation.

    c. The conceptual development and the cultural heritage of educationally deprived children is inferior to that of children in more favorable environments.

    d. Because of limited experiences, educationally deprived children are limited in their ability to communicate with others orally or by means of reading and writing.

    e. The child who grows up in a culture of poverty has a strong feeling of fatalism, helplessness, dependence, and inferiority in social situations.

    f. By the time educationally deprived children enter school they have absorbed the basic attitudes and values of their subculture of poverty. As a result they are not ready to take advantage of the educational opportunities in the school or of opportunities that may come as a result of changed conditions during their lifetime.

    g. Any significant change in the relative position of the educationally deprived child requires a preferential treatment that will compensate for his inadequacies. These children require modified teaching techniques and a specially constructed curriculum if they are to succeed in school. They need special materials and devices to fill the gaps in their experience.

h. The time of readiness to learn can be advanced and the quality of development can be enriched by working with educationally deprived children before they show overt signs of readiness.

i. Deprivation is largely due to failure of environmental agents:

   a. failure to provide children with necessary nourishment before they are ready to exercise specific capacities.

   b. failure to use and develop these capacities once they are ready for exercise.

j. Although the preschool years are characterized by the most rapid change and growth and so are the most important years, yet the adolescent years are also a period of rapid change and growth, hence, these years are fruitful ones for the re-orientation and development of educationally deprived children.

k. Wherever poverty exists throughout the world there is a remarkable similarity in the style of life which may be called a "culture of poverty". This culture provides the human beings living in it with a design for living that permits their survival. This similarity is found in the structure of families, in interpersonal relations, in value systems, in spending habits, and in their tendency to live in the present with little thought of the future. The high incidence of common law marriages and of households headed by women are characteristic of this culture wherever it occurs.

2. Guidelines Used to Determine Science Experiences for Educationally Disadvantaged Youth

   a. Classroom studies should be related to the students' contemporary experiences in their society. Certain aspects of historical development may be helpful, but a consideration of these for endorsement and clarification will come after the ideas are crystallized through concrete experiences.

b. A definite classroom situation must be provided in which new experiences with objects and events are related to past experiences in such a manner that new relationships are discovered. By associating several new experiences during a short period of time, an awareness of the basic principles that account for these experiences may be developed.

c. Science experiences must be developed from the common interests of the learners and result in an understanding of the basic principles of science that are related to these interests.

d. Initial learning of first level abstractions comes from observations of particular objects and events via all of the senses. First hand experiences should be emphasized.

e. There is a continuum in learning experiences that ranges from observation of particular objects and events, through those presented using multi-sensory aids, through the presentation of abstract concepts. Within the continuum of experiences, those located toward the concrete end are preferable.

f. Motivation for further learning will result from meaningful and enjoyable experiences with objects and events. Whenever possible "discovery" experiences should be planned for through "pre-eureka" procedures. Successful experiences in accounting for particular objects and events will provide motivation for additional experiences with other objects and events.

g. Audio-visual materials should be developed for use in initiating activities; for use in lieu of concrete experiences where these are impractical; and for use in providing additional enriching experiences.

h. The lack of communication skills and the lack of self-confidence make mandatory that educationally deprived children succeed in what they do. The tasks they undertake in school must be measured in difficulty and be ordered sequentially to guarantee success.

i. A wide range of materials together with opportunities to use these materials in meaningful ways must be provided if each educationally deprived child is to enhance his own self-confidence by noting his own growth in ideas and skills.

j. The major outcome of classroom experiences in science is to create in the educationally disadvantaged youth a desire to learn and a positive attitude toward school.

k. The school program should improve the basic skills of speaking and reading.

l. Culturally disadvantaged adolescents should be permitted to specialize in an area in which they are specially interested.

3. Guidelines Used to Determine How to Teach Science to Educationally Disadvantaged Youth.

   a. The teacher must accurately assess the strengths, weaknesses, and interests of each child in order to counsel and guide each in his pursuit of knowledge.

   b. Instruction will of necessity be largely with small groups rather than with the total class.

   c. The teacher must know the content and the processes of science; the childrens' environment, their fears and concerns, and be skillful in guiding their learning experiences.

   d. Educationally deprived adolescents will have had many frustrating experiences so special care must be taken to enable each to succeed in each task undertaken. This success should be used to reinforce and to motivate further learning.

e. The teacher must be willing for the child to deal primarily with specific objects, events, or persons as these objects, events or persons relate to himself, rather than to be concerned primarily with generalized activities.

f. The teacher as a discussion leader accepts every response as a contribution and by questions, suggestions, and vocabulary directs the development of the concept.

g. The teacher must be able to arrange a learning situation in which the youth's belief in himself, his self-image, escalates. Each must operate responsibly in a self-directed way to build a confident self-image.

h. The teacher should become an active partner with the pupils while maintaining an appropriate teacher image fostering abilities before, as well as during, the expected maturation time for these abilities.

i. Even though educationally deprived, each child will have had many experiences that may be used to promote learning.

j. The same concepts should be developed in several ways from a number of different but related experiences.

k. The major purpose of laboratory experiences is to promote creative thinking, not to manipulate equipment.

l. Reading materials should be selected to supplement the classroom actities out of which basic principles have been developed. In this way the basic principles may be firmly fixed in mind and also skills and habits of reading may be taught.

m. Assignments should be short. Emphasis should be on quality of work rather than on quantity of work.

n. Vocabulary load should be kept at a minimum level. Special effort should be made to teach the required vocabulary.

o. Mathematical calculations should be kept at a minimum level so that measurements and quantitative treatment of results enhances rather than stifles learning.

p. Testing should be used primarily to promote learning. It should be situation centered and involve such skills as interpretations of data, application of principles, the formulation of appropriate hypotheses, as well as to enable the student to assess his comprehension.

4. Guidelines Used to Select Science Experiences For Educationally Disadvantaged Youth

    a. Selection of topics for individual, small group or class investigation must provide avenues that insure success. Therefore, the investigation must center around directed inquiry rather than unassisted discovery.

    b. Each illustrative and investigative activity should:

        a. relate to the pupils' common experiences
        b. lead to a better understanding of the pupils' invironment
        c. stem from and enhance the pupils' interest
        b. be specific rather than generalized, especially at the beginning.
        e. furnish a basic for improving language skills, especially reading and oral expression
        f. be of measured difficulty so that each may succeed.

    c. Each piece of apparatus should be:

        a. simple so that attention may be focused on significant observations
        b. so designed as to clearly show-perhaps to magnify-the quality being observed.
        c. safe to use
        d. easy to manipulate
        e. relatively durable
        f. relatively inexpensive
        g. easy to store

INTRODUCTION

The teaching procedures offered in this program are experimental. The teacher is offered the flexibility required to meet the needs of the different pupils while directing their learning activities in a meaningful, sequential manner. The major emphases are placed on concrete experiences and the quality of experiences rather than on the quantity of content.

The material is written with the assumption that the students have a limited reading ability and a poor command of the English language. The formal textbook has been eliminated placing the responsibility of instruction entirely in the hands of the teacher. He must direct the learning processes by means of student-teacher verbal interactions with emphasis being placed on oral discussions, reinforcements, and the development of a sound scientific approach. One of the basic problem -- that of communication -- can be greatly alleviated by initially utilizing the students' colloquialisms. Extensive use of audio-visual materials is necessary to provide meaningful concrete experiences.

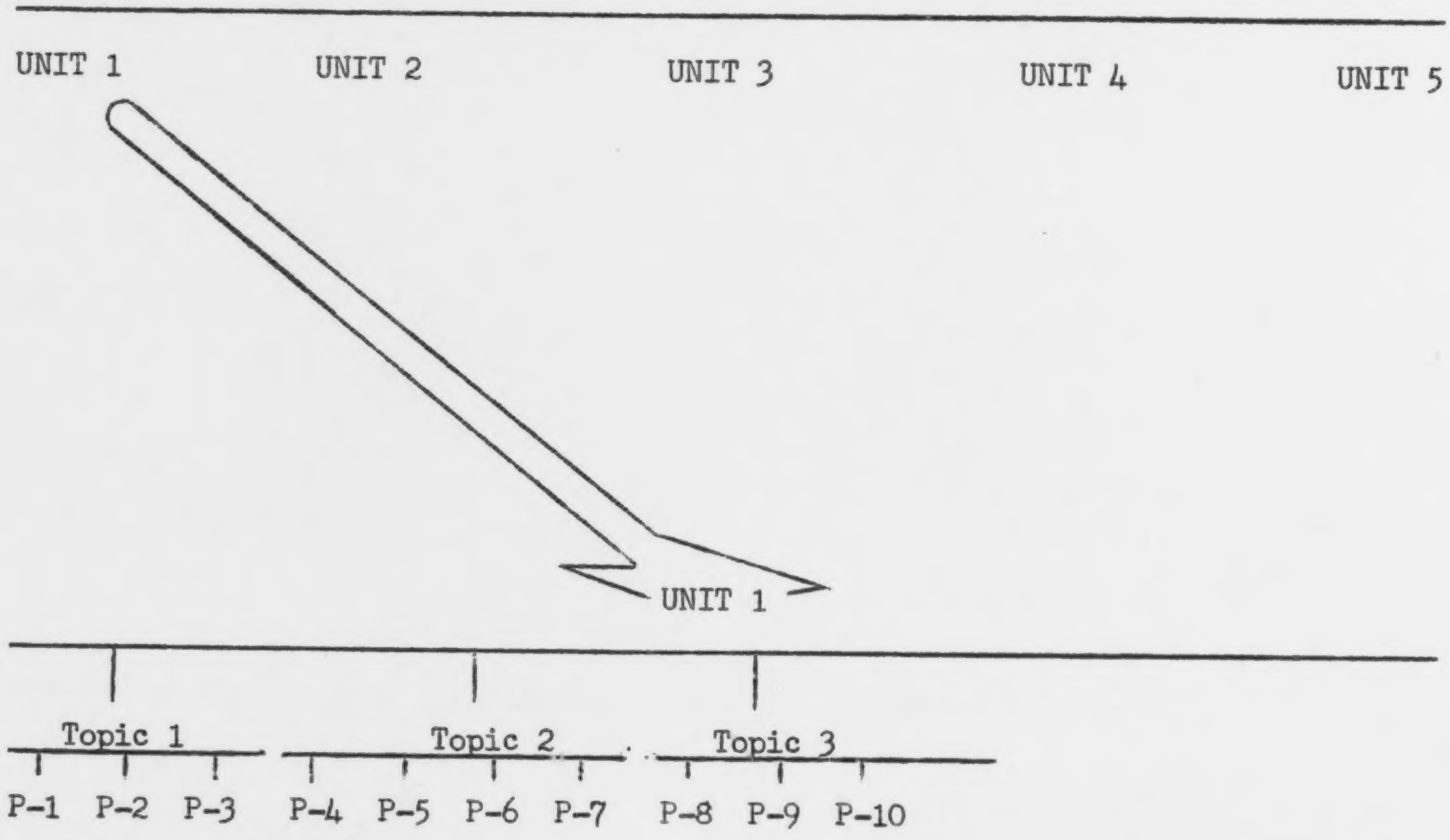
The teaching will normally progress through three phases:

1. Initial discussion supported by audio-visual materials to stimulate interest.
2. Small group laboratory activities supported by discussions of particular relevant information.
3. Final discussion to establish a conceptual framework and lead into the next topic.

A suggested format for the teacher to follow in directing the class is presented in detail. Suggested comments to be made by the teacher to the class are written in CAPITAL LETTERS; suggested procedures and anticipated responses are written in small type. Printed materials to be used by the students are designated by the letter "P" followed by a sequential number (P-2). These are to be issued to the students at the teacher's discretion. This manual is only a guide for the teacher in preparing for class. It is not a student manual.

This manual is separated into units. Each unit contains several topics (statements of concept) which are demonstrated by several student activities. This may be graphically represented as:

Physical Science Manual


UNIT 1
UNIT 2
UNIT 3
UNIT 4
UNIT 5
UNIT 1
Topic 1
Topic 2
Topic 3
P-1
P-2
P-3
P-4
P-5
P-6
P-7
P-8
P-9
P-10

The TEACHER RESOURCE section is provided for the convenience of the teacher as a quick reference for related factual material. This is not necessarily the material to be presented to the class. The TEACHER DIRECTION section provides the materials and procedures to be used in the classroom.

The student written materials are being provided for the experimental classes. A copy of each activity has been inserted following the teacher directions in the teacher's manual. They are arranged in the order that they would normally be distributed by the teacher. Additional copies may be made by the various means of duplication.

Transparencies have been prepared for the experimental classes and are labeled the same as the activities they are to supplement. Printed copies of these transparencies may be produced by various thermo processes.

This program is being developed upon principles, procedures, and techniques found to be effective in working with all children. The guidelines and assumptions basic to DISCUS are also basic to sound teaching practices and classroom behaviors in any part of the country.

The DISCUS program is written specifically for a select group of students in Jacksonville, Florida and therefore reflects the immediate community, appropriate reading level and a projected comprehension rate. Modifications to the program in these areas should make the DISCUS program appropriate for any group of students in any part of the country.

Topic 1 - The initiation of the discussion pattern is to establish rapport between the teacher and students.

The purpose of the introductory discussion is twofold; to establish a discussion pattern that reflects critical thinking and questioning, and to establish an initial rapport between the teacher and the students in the classroom. The topic consists of twenty-three separate optical illusions on transparencies to be placed on the overhead projector.[1] The students are to be encouraged to discuss the illusions freely and informally. It can be assumed that the students will be reluctant to participate for many reasons, some of which may be: (1) due to past experiences with failure, (2) peer group influences, (3) fear of giving wrong answers resulting in ridicule, and (4) being conditioned not to participate. The teacher must establish an atmosphere conducive to free discussion and questioning. Each student reply should be accepted, modified as necessary, and reinforced as a contribution. By design, optical illusions will serve this purpose quite well for there is not one entirely correct answer that can be determined without intensive questioning. Use as many of the illusions as needed to establish the initial rapport.

The optical illusions should stimulate interest and improve communication in all three phases of teaching. This introductory activity is designed to "break the ice" and for orientation. The teacher should talk as little as possible but should not be reluctant to capitalize on points and suggestions that lead to the development of the pre-determined goals--that is to establish rapport and critical thinking.

---

1. These may be purchased from the 3-M Company. Approximate cost is $35.00

Most of what the teacher says is said in question form rather than expository form. His responses to student statements are largely questions or suggestions. An example would be if a student questions whether or not a line is straight, suggest the use of a straight-edge to determine the answer. The results of the discussion should develop the idea that only through questions and investigations can answers and solutions be determined.

TEACHER DIRECTION

Place a transparency of an optical illusion on the overhead projector, WHAT DOES THAT THING LOOK LIKE? Encourage extensive discussion. Answer questions with question such as "What do you think it **is**?" or solicit voluntary answers from the class. Capitalize on and encourage students' suggestions for determining answers in a scientific manner such as observing, measuring, inferring, and experimenting.

Follow the same procedures for other transparencies.

In conclusion, point out that the same object may appear different to different individuals. This is a problem of science. Interject the idea that individuals are different in thought as well as appearance. Examples are how fat is "fat", how tall is "tall", where is "there".

UNIT 1 FIRST CLASS LEVERS

The purpose of Unit 1 is primarily to introduce the student to laboratory behaviors and techniques. The first activities use large, sturdy pieces of equipment and progress to more refined and delicate equipment. Hopefully the students will become confortable in a laboratory situation and will develop a respect and interest in the activities.

The activities included in Unit 1 are:

P-1	THE BIG STICK The Effect of Weights on the Lever
P-2	OFF-CENTER The Lever When the Turning Point is Not in the Middle
P-3	GETTING DEPENDABLE ANSWERS How a Scientist Works
P-4	THE SMOOTHER THE BETTER Increasing Accuracy with Levers Using More Accurate Equipment
P-5	GETTING TOUGH Moments of Force
P-6	GETTING TOUGHER Determining More Complex Moments of Force

TEACHER RESOURCE

Every time a person moves he exerts a force and does work. A force is a push or pull. If the force moves something in the direction of the force, work is done. Work may be expressed by the formula $W = F \times D$. Any unit of work (W) must include a force unit (F) and a distance unit (D). The force units used in these activities are those commonly used in measuring weights, namely: ounces, pounds, grams, kilograms, et. al. (The unites of force, dynes and newtons, and of work, ergs and joules, are too abstract for use here). Distances can be measured in inches, feet, centimeters, meters, et. al.

The resistances that are overcome by forces are gravity, inertia, and friction. It takes energy to lift something, to start something moving, to stop something when it is moving, or to push something over a rough surface or through any medium. Friction may be lessened by substituting smooth surfaces for rough surfaces, by lubrication, and by substituting rolling friction for sliding friction.

Power is the time rate of doing work. It takes twice as much power to do a given amount of work in half the time. Power (P) may be expressed by the formulas:

$$P = \frac{W}{T} \qquad P = \frac{F \times D}{T} \qquad P = \frac{\text{foot-pounds}}{\text{Seconds}}$$

Power is commonly measured in horsepower. One horsepower is 33,000 foot-pounds of work per minute, or 550 foot-pounds of work per second.

Machines are used to make work easier. There are simple machines and compound machines. Compound machines are made up of two or more simple machines which work together as a unit. Simple machines are of two kinds: machines that turn, namely; the lever, the wheel and axle, and the pulley; and machines that slide, namely; the inclined plane, the wedge and the screw.

The lever is a simple machine where an applied force, an effort force, can move objects which resist movement, a resistance force. Generally, the lever is used to move objects that are not easily moved by hand such that a small effort applied through a long distance will move a large resistance through a short distance. The relative location of the effort, resistance, and pivot or fulcrum is determined by the physical problem. The wedge is really two inclined planes placed back to back. The screw is an inclined plane wrapped around an axle.

When working with machines that turn, one makes calculations of moments. A moment, or torque, is a product of a force times its perpendicular distance from the fulcrum. The principle of moments used in this manual is that the machine is balanced when the sum of the moments which tends to turn the machine in a clockwise direction are equal to the sum of the moments which tends to turn the machine in a counter-clockwise direction

When working with machines we are interested in the efficiency and mechanical advantage of the machine. Input work is the product of the force times the distance the force moves with the force and distance measured along the same line. Output work is the product of the resistance force times the distance that it moves. The effeciency of a machine is the ratio of the output work to the input work. For an ideal machine, disregarding friction, input work equals output work. This is one way of expressing the fundamental principle of the conservation of mechanical energy. Due to friction, however, input work is always somewhat greater then output work and all real machines are less than 100% efficient. The apparent loss of energy is given up as heat.

The actual mechanical advantage of a machine is expressed as the resistance force divided by the effort force. For example, if an effort force of 10 lbs is applied to a lever and moves a resistance force of 80 lbs, then the lever has a M.A. of $\frac{80}{10} = 8$. The formula is

$$\text{M.A.} = \frac{\text{Resistance force}}{\text{Effort force}} \quad \text{or} \quad \text{M.A.} = \frac{R}{E}$$

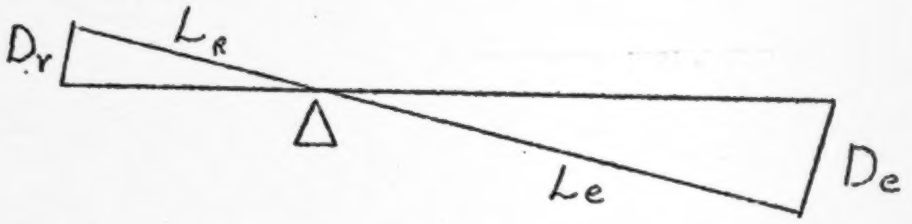
The theoretical mechanical advantage of any machine can be calculated by dividing the distance that the effort force moves by the distance the resistance force moves.

$$\text{M.A.} = \frac{\text{Distance the effort moves}}{\text{Distance the resistance moves}} \quad \text{or} \quad \text{M.A.} = \frac{De}{Dr}$$

In machines that turn the mechanical advantage is calculated by dividing the length of the effort arm by the length of the resistance arm.

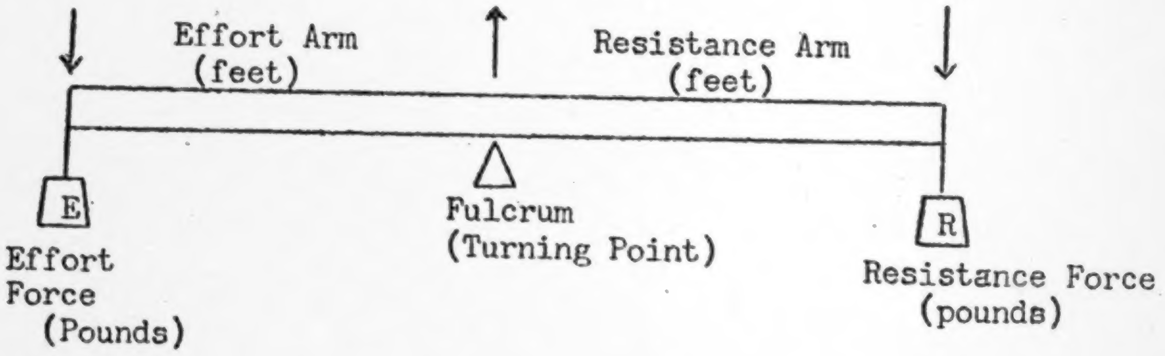
$$\text{M.A.} = \frac{\text{Length of the effort arm}}{\text{Length of the resistance arm}} \quad \text{or} \quad \text{M.A.} = \frac{Le}{Lr}$$

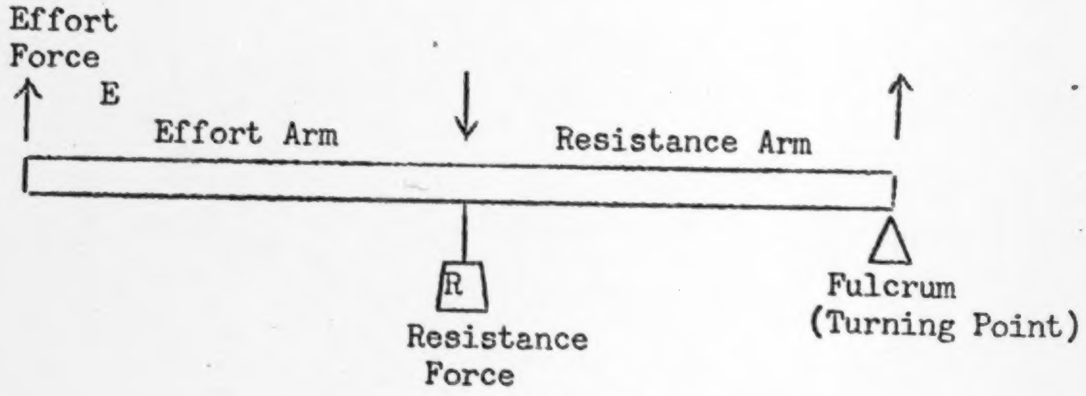
Teacher Resource
page 3

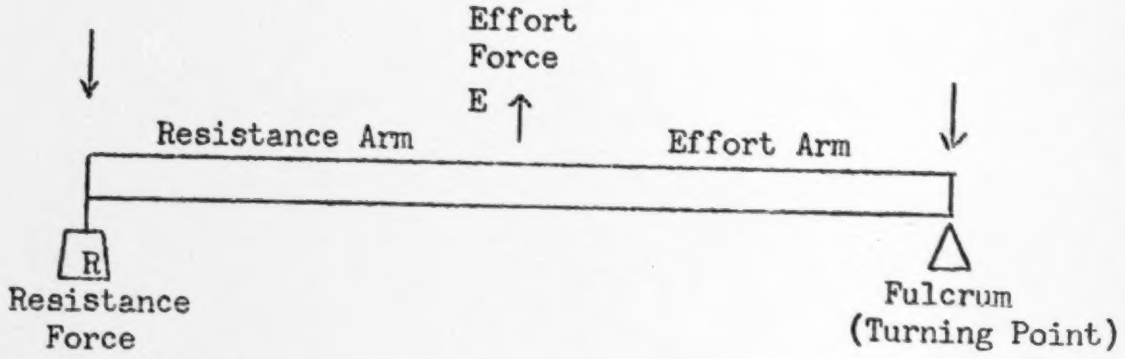


From the diagram we see that the large "effort" triangle is similar to the small "resistance" triangle and that the sides are proportional, $\frac{De}{Dr} = \frac{Le}{Lr}$. Therefore, the last two equations are identical - two ways of saying the same thing.

SEVERAL ARRANGEMENTS OF THE LEVER AS A SIMPLE MACHINE

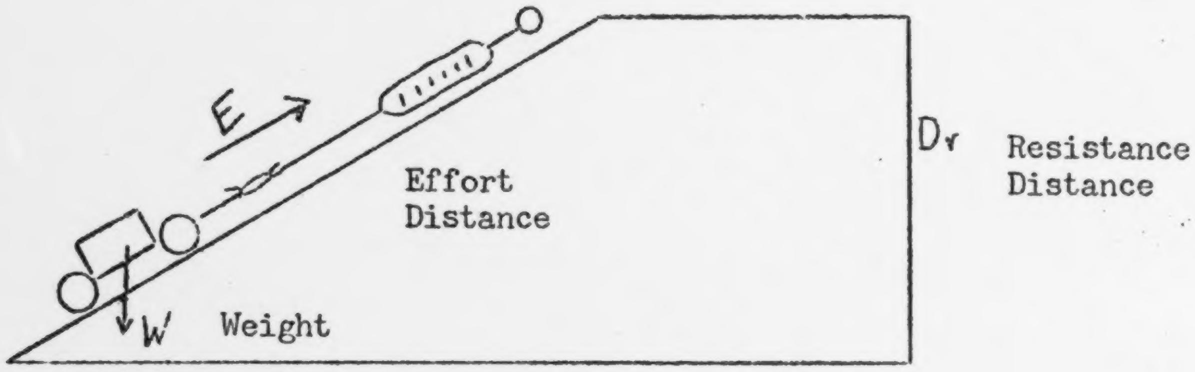

Effort Arm
(feet)
Resistance Arm
(feet)
E
Effort
Force
(Pounds)
Fulcrum
(Turning Point)
R
Resistance Force
(pounds)


Effort
Force
E
Effort Arm
Resistance Arm
R
Resistance
Force
Fulcrum
(Turning Point)


Effort
Force
E
Resistance Arm
Effort Arm
R
Resistance
Force
Fulcrum
(Turning Point)

The condition of equilibrium is obtained clockwise moments = counter-clockwise moments.

Inclined Plane


E
Effort Distance
Dr
Resistance Distance
W
Weight

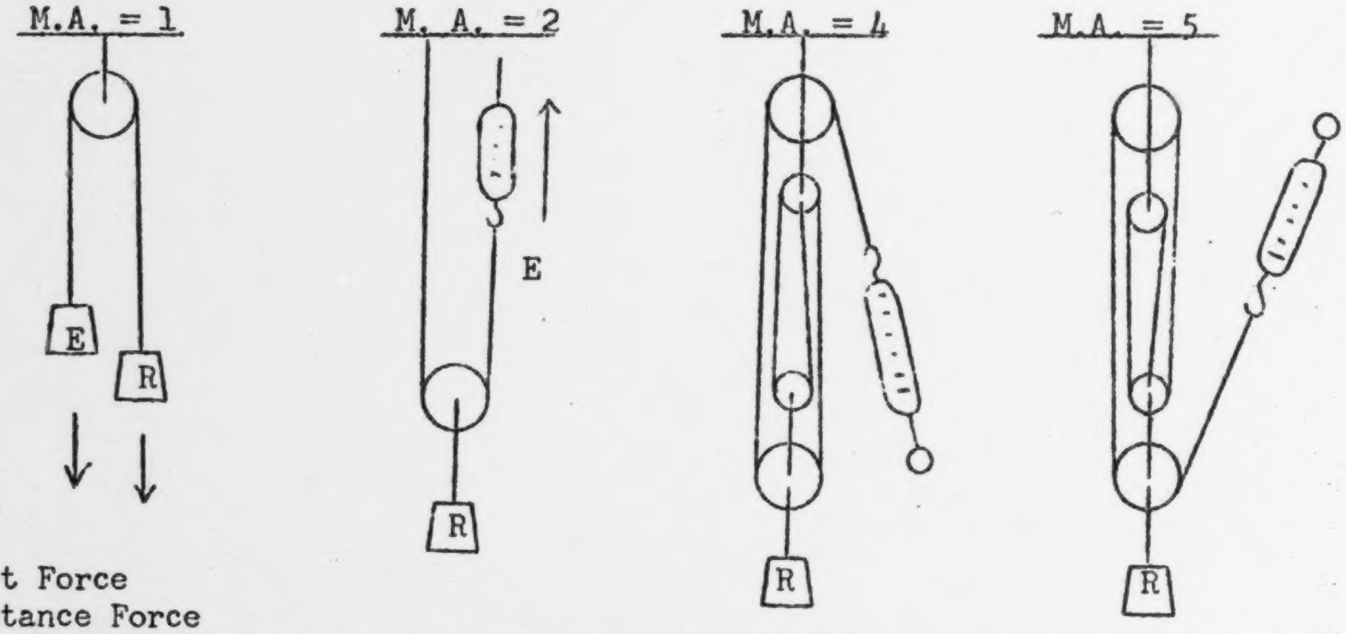
Input work = Effort force x Length of Plane (Both measured along the plane)

Output work = Weight of object x Height of Plane (Both acting and measured vertically)

Principle: Conservation of energy, disregarding friction,
Input work = Output work

The amount of energy required to move the resistance from the bottom of the plane to the top of the plane will be the same regardless of the path taken to get there.

Pulleys


M.A. = 1
E
R
M. A. = 2
E
R
M.A. = 4
R
M.A. = 5
R

E = Effort Force
R = Resistance Force
M.A. = Mechanical Advantage (number of supporting ropes)
Principle: Conservation of energy, disregarding friction
Input work = Output work

Topic 1 - The lever is a machine. The lever shows weight relationships.

SCIENTISTS INVESTIGATE EVERYTHING. THEY PLAY WITH ANYTHING THEY CAN GET THEIR HANDS ON. IT SEEMS THAT BY LOOKING AND MEASURING WHAT THEY SEE, THEY CAN FIND REASONS WHY SOME THINGS HAPPEN AS THEY DO. YOU HAVE DONE THE SAME THING MANY TIMES. FOR EXAMPLE, HOW MANY MACHINES HAVE YOU SEEN THIS WEEK?

List all responses on the overhead projector. Do not expect an immediate response. Also ask "how does it work?" Emphasis should be on leverage, turning, force, and work. These emphases will have to be made by the teacher as supporting remarks.

Place on the overhead projector a transparency showing several levers being used. The discussion should compare the items to a bar; stress the point of turning. Emphasize the meaning of work while casually inserting the terms force and weight.

HOW ABOUT YOU, ARE YOU A MACHINE? (Discussion) WHAT IS A MACHINE? (List all replies on the overhead projector). FROM OUR DISCUSSION WE CAN DEFINE A MACHINE AS SOMETHING THAT DOES WORK. SO TURN AROUND AND SHAKE HANDS WITH A FELLOW MACHINE.

LET'S TALK ABOUT YOUR ARM MACHINE. HOLD YOUR ARMS STRAIGHT OUT TO THE SIDE OF YOU. (Teacher demonstrates). NOW MOVE FROM SIDE TO SIDE THREE TIMES AND COME BACK TO BALANCE. (While arms are still straight out), HOLDING YOUR ARMS AS THEY ARE NOW, MR. MACHINE, WHAT WOULD YOU SAY BALANCE OR EQUILIBRIUM IS? Get one or two statements then tell the students to rest their arms.)

Discuss the idea of balance by giving other examples (carpenter's level, seesaw et al.) until this definition of balance is well understood. This is a special case of equilibrium which we shall apply when using the equal arm balance.

LET'S DEFINE BALANCE AS WHEN ARMS ARE THE SAME DISTANCE FROM THE FLOOR. ANYONE HAVE ANY OBJECTIONS?

Pass out P-1, page 1 only.

TEACHER DIRECTION

P - 1

THE BIG STICK

(The effect of weights on the lever)

Let the students voluntarily group themselves into groups of three:

Materials for groups of three:

1. Meter stick
2. Two wire hooks (to be used as hangers for washers)
3. Spike (long nail)
4. 5 washers (weights) (to be distributed with page 2)

The purpose of this first activity is to determine the nomenclature of the lever and to familiarize the student with the equipment.

Place a transparency of a meter stick, spike, hooks, and shoes (assembled) on the overhead projector. (Do not comment on this transparency).

THE SCIENTISTS GIVE EVERYTHING A NAME, SO LETS NAME THESE ITEMS. O.K.? (Hold up a meter stick) WHAT IS THIS? (Discussion) LETS CALL IT A STICK. (Place the spike through the middle hole in the stick and spin the stick.) WHAT ARE WE GOING TO CALL THIS PLACE WHERE IT IS TURNING? (Discussion) LET'S CALL IT A TURNING POINT.

NOW WE HAVE TO CALL THIS PIN SOMETHING. (Discussion) LET'S CALL IT A PIN. (Discussion)

BY USING THE HOOKS, STICK, AND THE PIN, FIND OUT WHICH OBJECTS ARE THE HEAVIEST AND RECORD YOUR RESULTS ON THE DIAGRAMS.

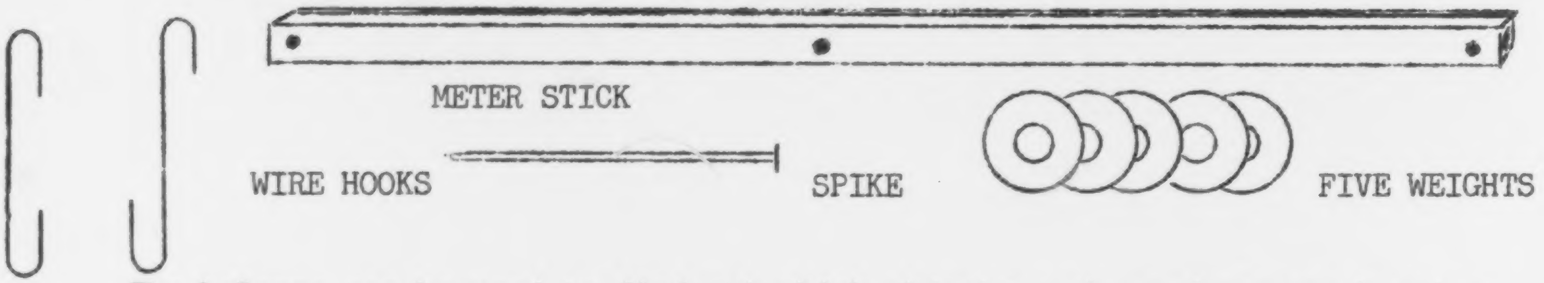
When the students have completed page 1, pass out page 2 of P-1.

STUDENT P - 1

THE BIG STICK

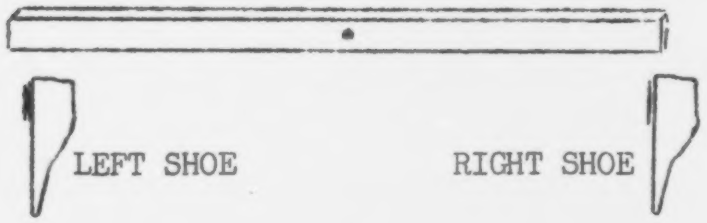
Materials for groups of three:

1. Meter stick
2. Two wire hooks
3. Spike
4. Five weights

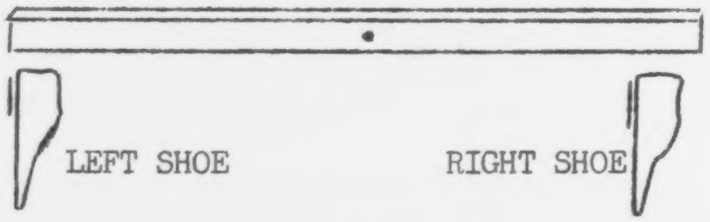

METER STICK
WIRE HOOKS
SPIKE
FIVE WEIGHTS

The balance can be used to find out which objects such as shoes are heavier. The heavier shoe will cause the stick to turn downwards and not be in balance. This idea of balance then can be a useful tool for finding out how much something weighs.

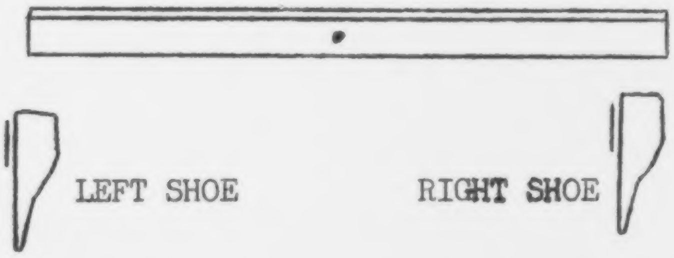
The stick, pin, and hooks are to be used to determine which shoes weigh more. The results are to be drawn on the diagrams below. If you do not understand, ask your instructor.


LEFT SHOE
RIGHT SHOE

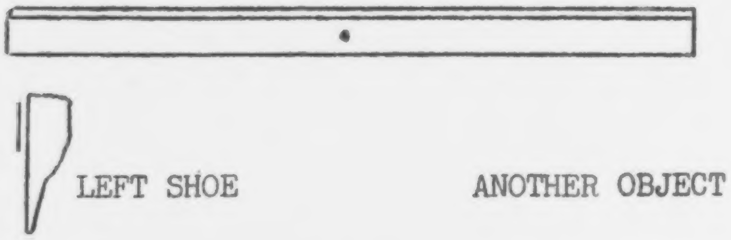
Which is heavier________________


LEFT SHOE
RIGHT SHOE

Which is heavier________________


LEFT SHOE
RIGHT SHOE

Which is heavier________________


LEFT SHOE
ANOTHER OBJECT

Which is lighter________________

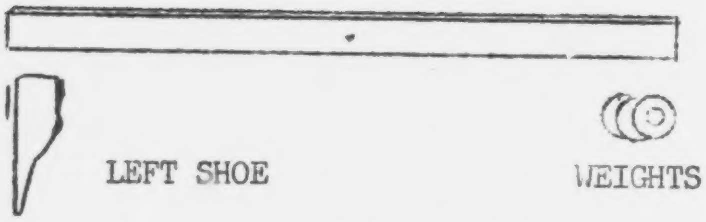
When you have completed this activity, obtain page 2 from your instructor.

Student
Page 2

Now that Activity 1 is completed, obtain weights from your instructor and find out how much the shoes really weigh. Be sure that the hooks are placed on the end of the stick.

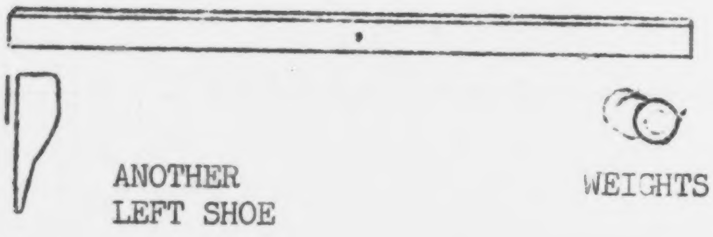
Find out how much the shoes weigh by using washers to balance the stick. The results are to be drawn on the diagrams below. How many washers does the shoe weigh? Weight may be expressed by the number of washers as well as in pounds or ounces.

1.


LEFT SHOE
WEIGHTS

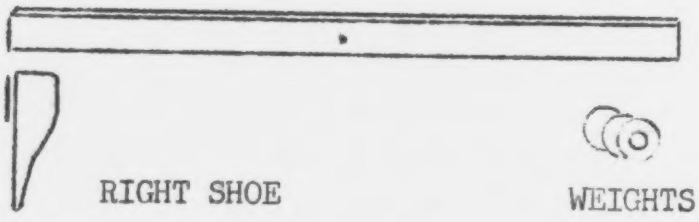
Whose shoe___________

Number of weights______


ANOTHER LEFT SHOE
WEIGHTS

Whose shoe___________

Number of weights_____


RIGHT SHOE
WEIGHTS

Whose shoe___________

Number of weights_____

Topic 2 - Moving the turning point on the lever changes the force requirements to balance the lever, to bring about an equilibrium condition.

THE IDEAS OF EQUILIBRIUM AND BALANCE ARE INTERESTING ONES AND SCIENTISTS HAVE LEARNED MUCH ABOUT THEM. ONE THING THEY OBSERVED IS THAT THE TURNING POINT DOES NOT HAVE TO BE IN THE MIDDLE OF THE STICK.

HOW COULD YOU BALANCE A LEVER IF THE TURNING POINT IS NOT IN THE MIDDLE?

The discussion should emphasize the weight relations and the length of the arm of the lever. Use in the discussion the words: lever arms, weights, force, turning point, and lever.

IF WHAT YOU SAY IS TRUE AND THE LEVER CAN BE BALANCED WHEN THE TURNING POINT IS NOT IN THE MIDDLE, YOU SHOULD BE ABLE TO SHOW IT. SO SHOW IT WITH THE MATERIALS YOU HAD IN THE LAST ACTIVITY. DO YOU THINK YOU CAN? LET'S FIND OUT.

Pass out P-2.

TEACHER DIRECTIONS P - 2

OFF - CENTER

(The lever when the turning point is not in the middle)

Materials for groups of three:

1. Meter Stick
2. Two wire hooks
3. Spike
4. Weights (washers)

The students are to place the hooks on the end of the stick, a shoe on the short end, and the weights on the long end, and then visa-versa. This is to introduce the idea of mechanical advantage. Mechanical advantage is not to be discussed at this time. HOW MANY WASHERS ARE NEEDED TO BALANCE THE STICK BEFORE THE SHOE IS ADDED.

THE LEVER HAS TWO DIFFERENT TYPES OF USES WHEN THE TURNING POINT IS NOT IN THE MIDDLE. THE NUMBER OF WEIGHTS NEEDED TO BALANCE THE SHOE IS VERY DIFFERENT WHEN THE SHOE IS AT DIFFERENT ENDS. YOU ARE TO FIND OUT THE NUMBER OF WEIGHTS NEEDED TO BALANCE THE LEVER WHEN THE SHOE IS ALTERNATELY PLACED ON EACH END. I THINK YOU ALREADY KNOW, BUT YOU MUST SHOW IT.

Place a transparency on the overhead projector showing the shoe and weights in the correct places, but do not mention it to the class.

After P-2 is completed, the class is to reassemble for a discussion of results and principles using a prepared transparency. The introduction of the term DATA is to be used but not stressed. The terms DATA and INFORMATION can be used interchangeably. There should be no effort made to force the term data, but make repeated use of the term both verbally and in written form.

This discussion will be centered around the instructor who is verbally asking for results in the large group and writing the data on the overhead projector. Do not use a structured approach. From voluntary statements gather data.

YOU SHOULD NOW KNOW A LOT ABOUT YOUR SHOES. YOU HAVE WEIGHED THEM, SMELLED THEM, AND COMPARED THEM TO GATHER YOUR DATA. LET'S FIND OUT WHO HAS THE HEAVIEST SHOE AND WHO HAS THE LIGHTEST SHOE.

Teacher Direction
Page 2

Using a prepared transparency, record all data. You may question the validity of some of the results, but record them anyway. If students question the results, encourage questioning and ask for proof by taking time to perform the activity needed to test it. The selection of students to perform the activities in front of the class should reflect good judgement. It will be necessary to use the lever of the group in question. If unable to select a student, then the teacher should demonstrate by setting up a lever. If students fail to question the validity of unusual results then the teacher should encourage questions concerning the validity by asking leading questions.

After the heaviest shoe and the lightest shoe have been selected the discussion should lead into mechanical advantage. The important idea to stress is that in leverage it makes a great deal of difference when you change the position of the turning point. This should be obvious to the students at this point but a verbal acknowledgement should be given. This can be accomplished by referring to a car stuck in the sand and the use of a large pole as a lever to move the car.

YOU KNOW IT MAKES A LOT OF DIFFERENCE WHERE THE SHOE IS LOCATED ON THE STICK. IF IT IS ON THE SHORT END OF THE STICK YOU CAN MOVE IT MORE EASILY THAN IF IT IS ON THE LONG END OF THE STICK. RIGHT?

(Other examples can be used. How would a house mover lift the corner of a house?)

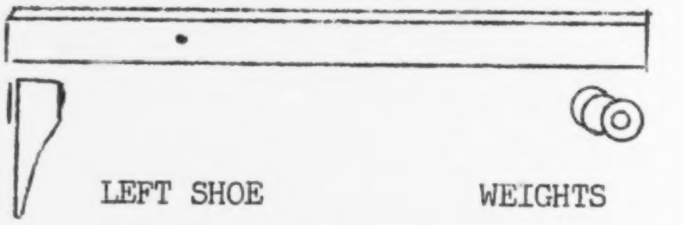
STUDENT P - 2

THE LEVER WHEN THE TURNING POINT IS NOT IN THE MIDDLE

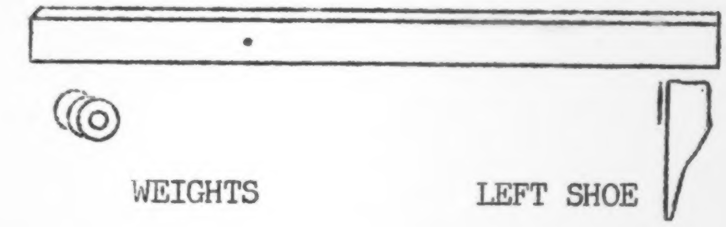
Materials for groups of three:

1. Meter Stick
2. Spike
3. Two wire hooks
4. Weights and bag of sand.

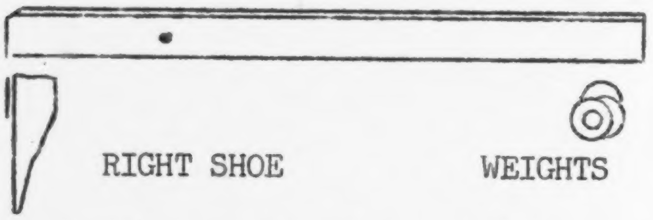
The lever can be used to find out how much objects weigh. You will know the number of weights needed when the stick is in balance. To balance the stick place a shoe (or the object to be weighed) on one end and the weights on the other end. Determine the number of weights needed to balance the lever when the turning point is not in the middle of the lever. The results are to be recorded on the diagrams below. If you do not understand, ask your instructor.


LEFT SHOE
WEIGHTS

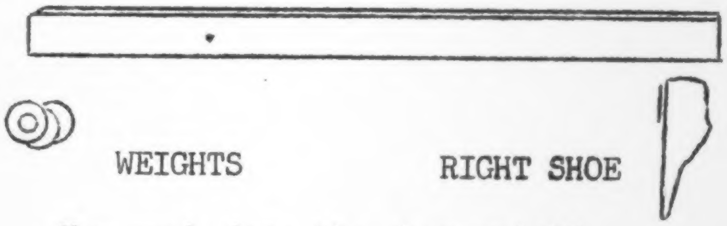
How much does the shoe weigh?_______


WEIGHTS
LEFT SHOE

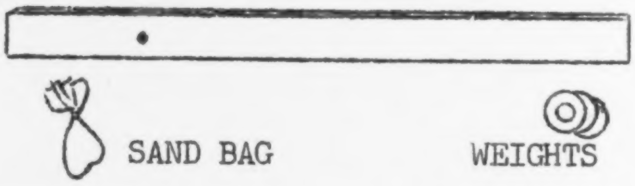
How much does the shoe weigh?________

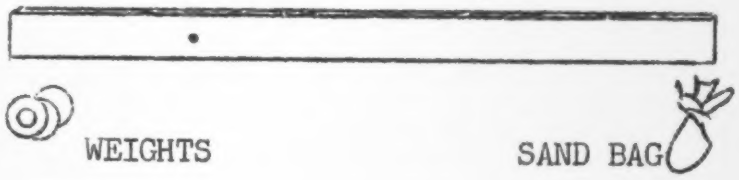

RIGHT SHOE
WEIGHTS

How much does the shoe weigh? _____


WEIGHTS
RIGHT SHOE

How much does the shoe weigh?_________


SAND BAG
WEIGHTS


WEIGHTS
SAND BAG

How much does the sand weigh? _________

Heaviest shoe .... ________Weights

Lightest shoe .... ________Weights

Bag of sand .... ________ Weights

How much does the sand weigh?__________

Heaviest shoe .... ______ Weights

Lightest shoe .... ______ Weights

Bag of sand .... ______ Weights

TEACHER DIRECTION

P - 3

GETTING DEPENDABLE ANSWERS

(How a Scientist Works)

Materials for groups of three:

1. Meter Stick
2. Spike

The following discussion should lead the class into a more scientific approach in investigating the lever. The meter stick had many inadequacies: such as irregularities in density of the stick and friction at the fulcrum, and these inadequacies when critically analyzed should reveal the need for better equipment and a more refined technique. The term FRICTION should be introduced as it applies to the fulcrum.

Pass out the meter stick and spike used in P-2.

LOOK AT YOUR METER STICK AND MOVE IT VERY SLOWLY ON THE SPIKE. (The teacher should demonstrate both turning and sliding movements.)

NOW, LET'S CRITICIZE OUR RESULTS FROM THE PREVIOUS ACTIVITIES. WHAT THINGS CAN YOU SEE THAT WOULD CAUSE YOUR RESULTS TO BE INACCURATE? (List all responses on the overhead projector). Stress friction. State ways that it may be reduced. Encourage the need for equipment to overcome the inadequacies making references to the equipment to be used in the following activities. An example is the use of a thin edge in the place of a spike for the fulcrum to reduce friction.

Pass out P-3

The reading material should reinforce the above discussion. The terms INTERPRETING AND OBSERVATIONS in the reading material may be new words and must be clarified before the students begin reading. The discussion following the activity is to reinforce the reading material and give the students confidence in their reading ability. The teacher should commend the students whenever possible for getting so much out of their reading assignment. A short discussion of the points in the last paragraph will be needed. This discussion should introduce P-4.

STUDENT P - 3

GETTING DEPENDABLE ANSWERS

The scientist writes and discusses what he finds with many people. This is his way of checking on himself. People ask him many questions about his findings and tell him how they feel about them. If the scientists can't answer some questions, he tries to find out the answers. Usually he returns to his laboratory to think about his problem, read about what others have done already, and then organize another experiment. He will usually get better equipment so that he can obtain more accurate information, or data. This is important, for it would be hard to get dependable answers from equipment that was not accurate.

After the scientist has obtained improved equipment and done much reading and listening, he does the experiment again. In the case of levers, he knows that equilibrium is important. He knows that friction at the turning point (fulcrum) is not good. He also knows that all measurements are very important and that the weights must be accurately counted.

The scientist gets dependable answers by experimenting, observing the action, recording the data, and then interpreting the data. Only by being very careful and accurate in performing experiments can he get these consistant results.

TEACHER DIRECTION

P - 4

THE SMOOTHER THE BETTER

(Increasing Accuracy with Levers)

Materials for groups of three:

1. 1 wood ruler
2. 1 hardboard 5" x 13"
3. 2 slotted hardboard supports
4. 1 plastic tube
5. 1 fulcrum bracket (pin)
6. 1 lever holder
7. 2 bolts and nuts
8. 6 washers (weights)

Pass out P-4, page 1

The students are to follow teacher instructions in assembling their apparatus and not get ahead. The teacher should have a preassembled model.

ATTACH THE FULCRUM BRACKET TO THE HARDBOARD WITH THE TWO BOLTS AND NUTS. (The teacher should show the position on the assembled model for all steps). NEXT, ATTACH THE SLOTTED HARDBOARD SUPPORTS TO THE HARDBOARD AND INSERT THE PLASTIC TUBING FOR STABILITY. Pause. NEXT, SLIP THE METAL LEVER HOLDER ON THE RULER IN THE MIDDLE AT ZERO. MAKE SURE YOU DO NOT GET IT UP-SIDE-DOWN. NOW PLACE THE LEVER BRACKET ON THE FULCRUM BRACKET. Pause. IT IS IN BALANCE? IF NOT, ADJUST IT.

PLACE A WEIGHT ON THE LEFT SIDE OF THE LEVER SO THAT YOU CAN SEE THE NUMBER 10 THROUGH THE HOLE. Pause. IS YOUR LEVER IN BALANCE? (Discussion) Demonstrate on the overhead projector

PLACE A WEIGHT ON THE RIGHT SIDE OF THE LEVER SO THAT YOU CAN SEE THE NUMBER 10 THROUGH THE HOLE. IS YOUR LEVER IN BALANCE? IN EQUILIBRIUM? Pause. HOW DO YOU KNOW?

PLACE A WEIGHT ON THE LEFT SIDE OF YOUR LEVER SO THAT YOU CAN SEE THE NUMBER 6 THROUGH THE HOLE. IS YOUR LEVER IN BALANCE? IN EQUILIBRIUM? (Discussion)

PLACE ANOTHER WEIGHT ON THE RIGHT SIDE OF THE LEVER SO THAT YOU CAN SEE THE NUMBER 7 IN THE HOLE. IS YOUR LEVER IN BALANCE? IN EQUILIBRIUM? Pause. HOW DO YOU KNOW? (Discussion). WHERE SHOULD THE WEIGHT ON THE RIGHT SIDE BE PLACED FOR THE LEVER TO BALANCE? (6) (Discussion) FOLLOW THE DIRECTIONS AND COMPLETE THE ACTIVITY. (Discussion).

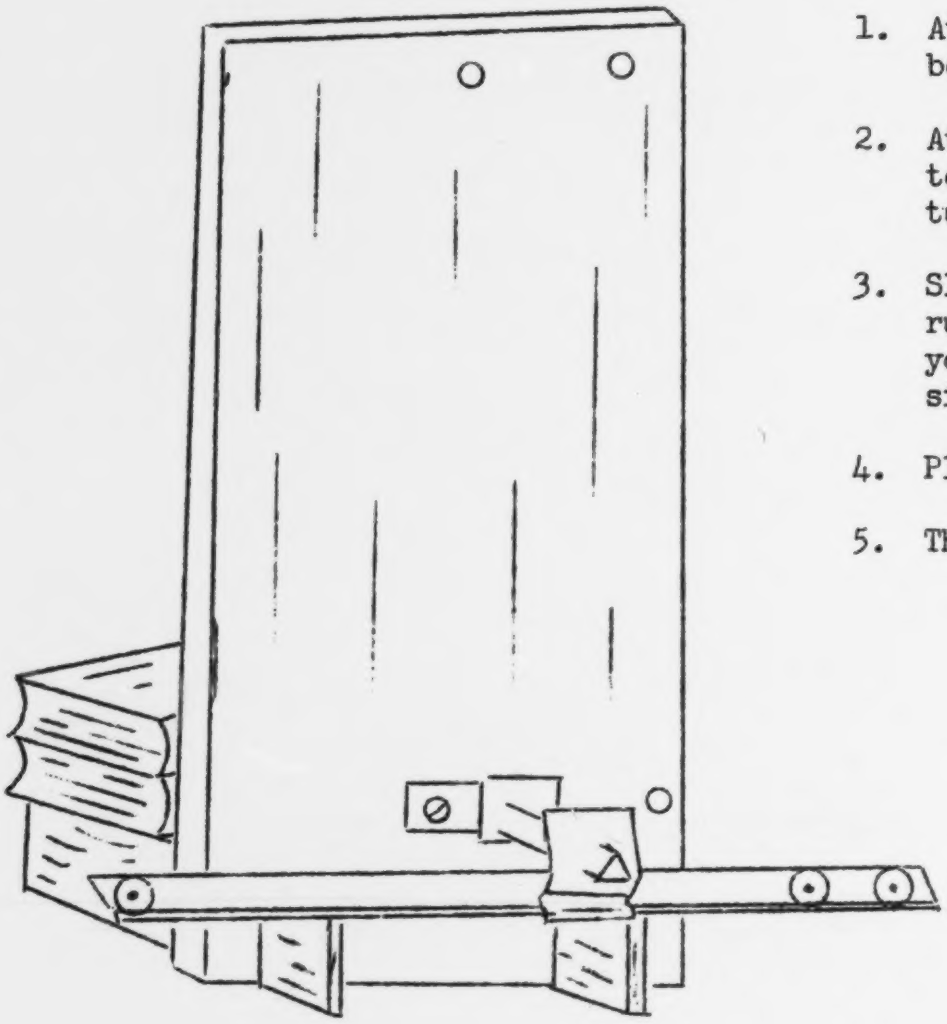
STUDENT

P - 4

THE SMOOTHER THE BETTER

Materials for groups of three:

1. 1 wood ruler
2. 1 hardboard 5" x 13"
3. 2 slotted hardboard supports
4. 1 fulcrum bracket (pin)
5. 1 plastic tube
6. 1 lever holder
7. 2 bolts and nuts
8. 6 weights

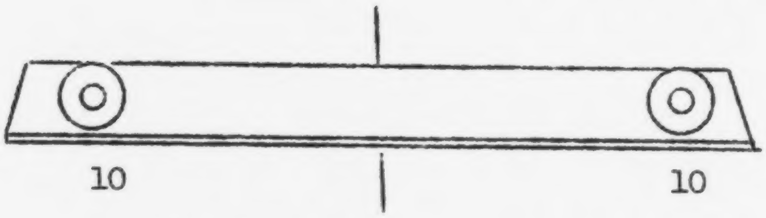


1. Attach the fulcrum bracket to the hardboard with the two bolts and nuts.
2. Attach the slotted hardboard supports to the hardboard and insert the plastic tubing for support.
3. Slip the metal lever holder on the ruler in the middle of 0. Make sure you do not get the ruler in the upside-down way.
4. Place the lever on the fulcrum bracket.
5. The lever should now be in balance.

Student
Page 2

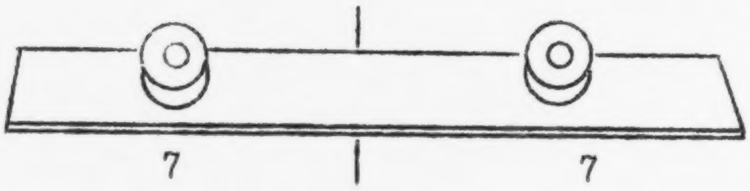
Place the weights on the numbers indicated in the drawings below and answer the questions. If you do not understand, ask your instructor for assistance.

1. Place a washer on 10 on the left side and another on 10 on the right side.



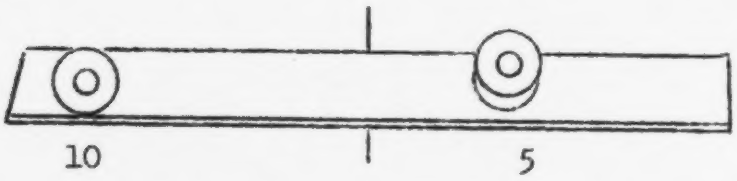
Is the lever in balance?

2. Place 2 washers on 7 on the left side and 2 washers on 7 on the right side.



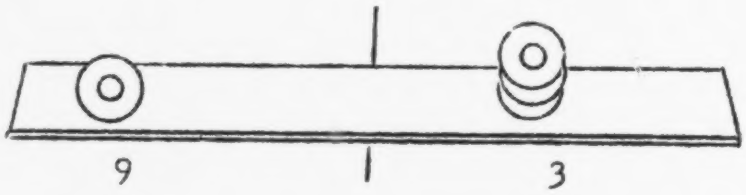
Is the lever in balance?

3. Place a washer on 10 on the left side and 2 washers on 5 on the right side



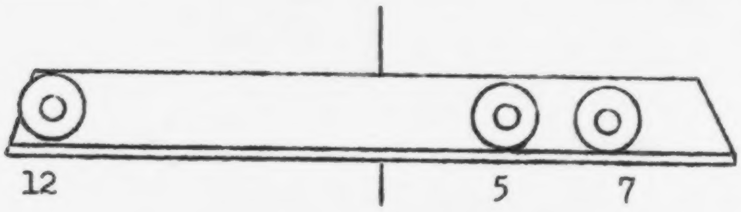
Is the lever in balance?

4. Place 3 washers on 3 on the left side and one washer on 9 on the right side.



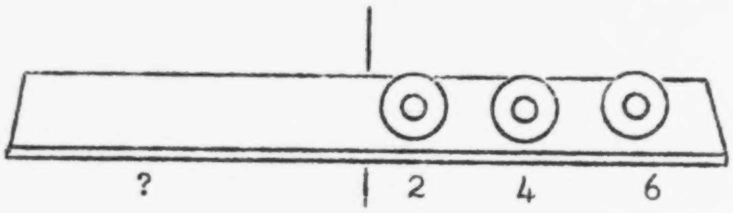
Is the lever in balance?

5. Place one washer on 5 and another washer on 7 on the left side. Place a washer on 12 on the right side.



Is the lever in balance?

6. Place a washer on 2, 4, and 6 on the left side. Where would you place 2 washers on the right side.



Is the lever in balance?

Topic 3 - A moment of force is the force times the shortest distance from the turning point.

P - 5

TEACHER DIRECTION

GETTING TOUGH

(Moments of Force)

Materials for groups of three:

1. 1 wood ruler
2. 1 hardboard 5" x 13"
3. 2 slotted hardboard supports
4. 1 plastic tube
5. 1 fulcrum bracket (pin)
6. 1 lever holder
7. 2 bolts and nuts
8. 6 washers (weights)

This activity will introduce the term and concept of 'moment of force', but the term is not to be stressed at this time.

Pass out P-5

ASSEMBLE YOUR APPARATUS THE SAME WAY YOU DID IN P-4. FOLLOW THE SAME PROCEDURE USING THE INFORMATION GIVEN IN THE TABLE AND DETERMINE THE POSITION THAT BRINGS THE LEVER INTO BALANCE. RECORD YOUR RESULTS UNDER POSITION ON THE RIGHT SIDE OF THE TABLE.

Demonstrate the correct procedure and record the first line of the table on transparency P-5. Instruct the students to obtain the data needed to complete the table.

NOW LET'S TRY TO INTERPRET THE DATA. WHAT CAN YOU FIGURE OUT FROM THE TABLE? (If the blank space is not mentioned, call it to their attention). LET'S FILL IN THE BLANK COLUMN ON THE LEFT SIDE AND THE RIGHT SIDE ON THE TABLE. ON THE FIRST LINE, LET'S MULTIPLY THE NUMBER OF WEIGHTS COLUMN TIMES THE POSITION COLUMN AND RECORD THE ANSWERS IN THE BLANK SPACES. FIRST, MULTIPLY 2 TIMES 6. Pause, WHAT DID YOU GET? (12). RECORD THAT NUMBER IN THE BLANK SPACE. (Discussion). NOW MULTIPLY 2 TIMES 6 ON THE RIGHT SIDE. Pause. WHAT DID YOU GET? (12). RECORD THAT NUMBER

IN THE BLANK SPACE. (Discussion) Complete the chart in a similar manner. DO YOU KNOW WHAT SCIENTISTS CALL THESE RESULTS IN THE BLANK SPACES? Pause. MOMENTS. SO WRITE MOMENTS IN THE CHART. (Discussion) Write "MOMENTS" on the transparency.

The following discussion is to develop the "if - then" approach to learning. The if-then approach to learning is a way of relating effects to causes. IF certain things happen, THEN certain other things will happen. For example, IF two cars are approaching each other in the same lane at high speeds, THEN a collision will occur. The if-then approach is a way of predicting occurrances. Instead of "if-then", the term "would you believe" will be used.

Instruct the students to get a pencil and a sheet of paper.

WOULD YOU BELIEVE, THAT IF TWO WEIGHTS WERE ON 5 ON THE LEFT SIDE, THE MOMENT WOULD BE 10? YES. (Using the overhead projector, make sure the students understand the procedure). Then make this a game by asking the students to pose questions. You may have to give several more examples and the students may not choose to ask questions readily, but be persistent and try to make it into a game.

WOULD YOU BELIEVE, THAT THE CLOCKWISE MOMENTS WOULD EQUAL THE COUNTER-CLOCKWISE MOMENTS AND THE BAR WOULD BE IN BALANCE IF THERE WERE TWO WEIGHTS ON 5 ON THE LEFT SIDE, AND ONE WEIGHT ON 10 ON THE RIGHT SIDE. Develop this by using the same procedure as above.

STUDENT

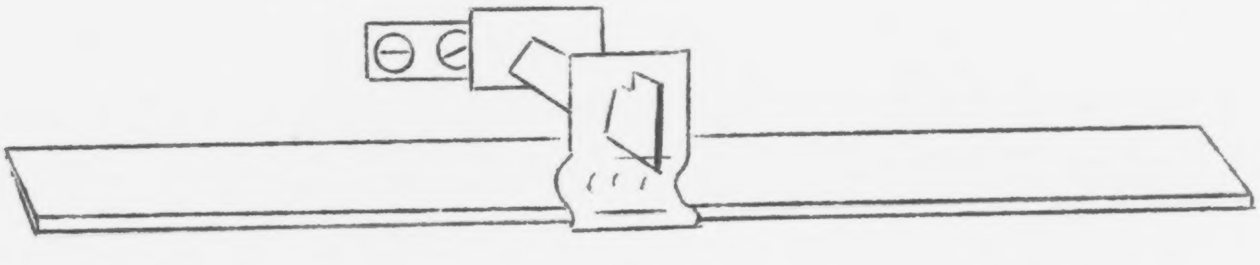
P - 5

GETTING TOUGH

Materials for groups of three:

1. 1 wood ruler	5. 1 plastic tube
2. 1 hardboard, 5" x 13"	6. 1 lever holder
3. 2 slotted hardboard supports	7. 2 bolts and nuts
4. 1 fulcrum bracket	8. 6 weights

Many scientist use the same method for solving a problem. First, they determine what questions need to be answered and then try to think of some possible answers. Next, they experiment, collect their data, and place it in a table similar to the one on the next page. Then they try to answer their questions from the information recorded in the table and by discussing it with other scientists.



In this activity you will need to stack the weights on top of each other. Place the required number of weights on the left side and then find out where the weights need to be placed on the right side to balance the lever. You can probably tell just by looking at the table, but try to do it out on the lever anyway. You can tell how many weights are needed from looking at the table.

Student
Page 2

Complete the table below by filling in the blank column on the right side under "Position" by experimentation. Remember, your lever must come to balance before you have found the correct answer.

LEFT SIDE			RIGHT SIDE		
Number of Weights	Position		Number of Weights	Position	
2	6		2		
2	6		1		
3	4		2		
3	5		1		
3	3		1		
2	6		4		
4	4		2		
1	12		3		

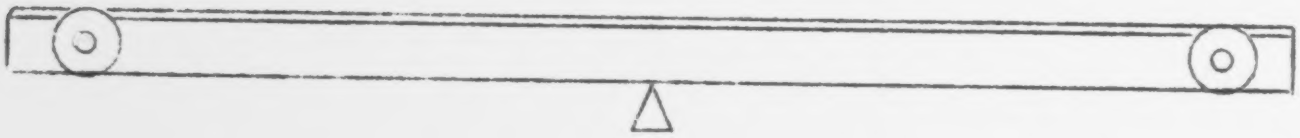
After completing the experiment, take your apparatus apart and return it to the proper place.

TEACHER RESOURCE P - 6

GETTING TOUGHER

(Determining More Complex Moments)

This activity is to develop the concept of total moments of force. The total moments of forces can be determined by adding all of the moments tending to produce a rotation of the system. The total clockwise moments must equal the total counterclockwise moments to produce equilibrium or balance.



If each force (E) and (R) = 1 Weight (washer)

Counterclockwise moments = Sum of clockwise moments

E x D (effort) = $R_1 \times D_1 + R_2 \times D_2$ (Resistance)

$1 \times 7 = 1 \times 2 + 1 \times 5$

$7 = 2 + 5$

$7 = 7$

The lever is therefore in equilibrium and balanced because the moments are equal.

The direction in which the force is being exerted and the line of action of the force relative to the fulcrum determines whether the force causes a clockwise or counterclockwise moment.

TEACHER DIRECTION

P - 6

GETTING TOUGHER

(Determining More Complex Moments)

Materials for groups of three:

1. 1 wood ruler
2. 1 Hardboard 5" x 13"
3. 2 Slotted hardboard supports
4. 1 Plastic tube
5. 1 Fulcrum bracket
6. 1 Lever holder
7. 2 Bolts and nuts
8. 6 Washers (weights)

ASSEMBLE YOUR APPARATUS THE SAME WAY YOU DID IN P-5. DO NOT BEGIN THE EXPERIMENT UNTIL ALL HAVE COMPLETED ASSEMBLING THE APPARATUS. WE WILL DO THE FIRST COUPLE OF PROBLEMS TOGETHER. SO, DO NOT BEGIN UNTIL ALL ARE READY. Pass out P-6.

The students are to follow along with their apparatus as the teacher demonstrates on the overhead projector with the prepared transparency. While leading a discussion, make sure all are following your instructions. The students are to follow the demonstration diagram on the first page P-6. After completing the demonstration, have the students complete the table on the second page of P-6.

After the apparatus has been disassembled and replaced, begin the discussion of the activity in the class group using the overhead projector and the prepared transparency of the table. The students should have pencil and paper for calculations.

NOW, LET'S LOOK AT THE TABLE AND TRY TO INTERPRET THE DATA. WHAT CAN YOU FIGURE OUT FROM THE TABLE?

If the blank space is not mentioned, call it to the students' attention. The teacher should proceed to fill in the table as in P-5. Some emphasis by the teacher will be necessary to dramatize the relationship of moments of force. In this discussion, the term MOMENTS OF FORCE should be used freely. Compliment student usage of the term.

The following discussion is to continue the "if - then" approach to learning. Instead of "if - then", the term "would you believe" may be used.

"WOULD YOU BELIEVE", THAT IF ONE WEIGHT WAS PLACED ON THREE AND ONE WEIGHT WAS PLACED ON FIVE ON THE SAME SIDE, THEN THE MOMENTS WOULD BE EIGHT?

Yes. Proceed with individual calculations followed by demonstrations using the overhead projector and a preassembled apparatus. WOULD YOU BELIEVE, THAT FOR EQUILIBRIUM, THE MOMENTS OF FORCE ON THE OPPOSITE SIDE WOULD HAVE TO BE EIGHT? Yes.

You may have to give several more examples to encourage students to pose similar questions, but be persistent and try to make it into a game. Attempt to get all the students to participate. Explain the use of the terms clockwise and counterclockwise to designate the direction of rotation of the lever.

WOULD YOU BELIEVE, THAT IF TWO WEIGHTS WERE PLACED ON 4, ON THE LEFT SIDE, THAT THE COUNTERCLOCKWISE MOMENTS OF FORCE WOULD BE 8? Yes. (Discussion).

"WOULD YOU BELIEVE", THAT IF ONE WEIGHT WAS PLACED ON 4, AND ONE WEIGHT WAS PLACED ON 6 ON THE RIGHT SIDE OF THE LEVER, THAT THE LEVER WOULD BALANCE IF TWO WEIGHTS WERE PLACED ON 5 ON THE LEFT SIDE OF THE LEVER? Yes

Student participation and demonstration on a preassembled apparatus will be necessary. Have them identify the clockwise and counterclockwise moments. Have the students, as a group, suggest several combinations to further investigate moments. Or small groups may develop their own table and then test their predictions.

STUDENT

P - 6

GETTING TOUGHER

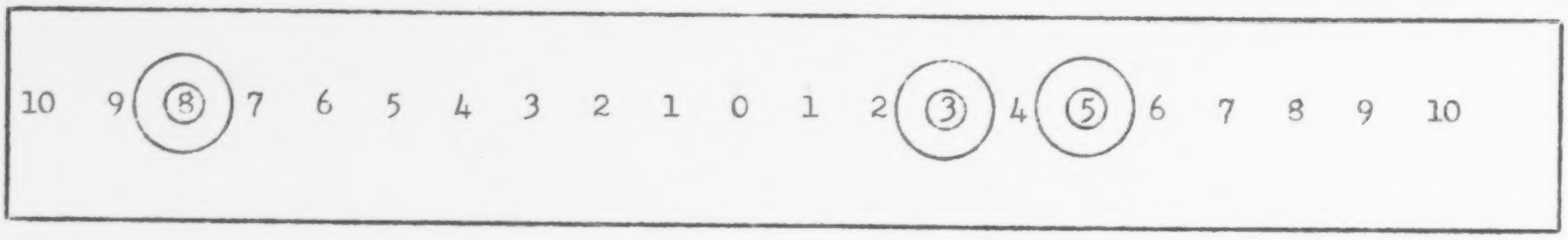
Materials for groups of three:

1. 1 wood ruler
2. 1 hardboard, 5" x 13"
3. 2 slotted hardboard supports
4. 1 fulcrum
5. 1 plastic tube
6. 1 lever holder
7. 2 bolts and nuts
8. 6 weights

In our early discussions, we found that when the lever was in equilibrium and balanced the clockwise moments of force were numerically equal to the counterclockwise moments of force. Remember how you found out what the moments were? You just multiplied the shortest distance of the weights from the turning point times the number of weights. One thin you should keep in mind during this activity is that moments can be added if they are on the same side of the fulcrum. It seems then, that the moments determine when things are in equilibrium and balanced: the total moments must be the same on each side, that is, the clockwise moments equal the counterclockwise moments.

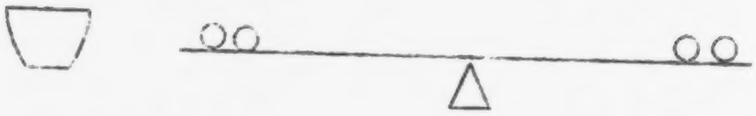
Let's collect some data using your apparatus and find out more about moments. Obtain the data as directed by your instructor and complete the table on the next page. Fill in the column under "Moments" for the clockwise (right side) and counterclockwise (left side) values. Remember, your lever must be in balance to obtain accurate data.

To help you understand the table, your instructor will work the first one with you using the diagram below.



Student
page 2

Moment of Force



Number	COUNTERCLOCKWISE Left Side			CLOCKWISE Right Side		
	Weight	Position	Moment	Weight	Position	Moment
1	1	8		1	3	
			00	1	5	
	TOTAL			TOTAL		
2	1	10		1	7	
			00	1	3	
	TOTAL			TOTAL		
3	1	4		1	12	
	1	8				
	TOTAL			TOTAL		
4	1	14		1	6	
			00	1		
	TOTAL			TOTAL		
5	1	13		1	5	
			00	1		
	TOTAL			TOTAL		
6	1	3				
	1	8				
	TOTAL			TOTAL		
7	1	5		1		
	1	9				
	TOTAL			TOTAL		
8	1			1	3	
				1	6	
	TOTAL			TOTAL		

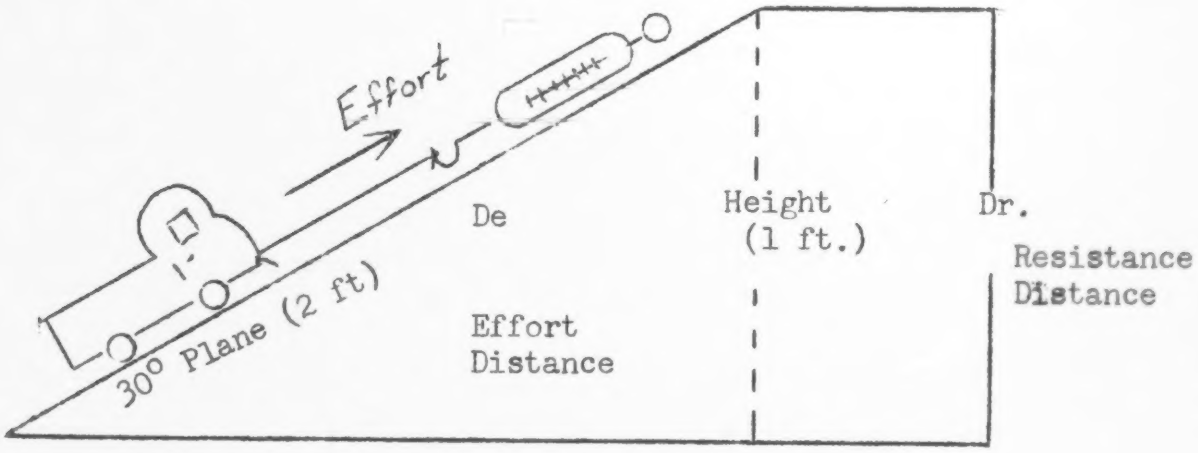
UNIT 2 INCLINED PLANE

The purpose of Unit 2 is to develop the concepts of work and power. The inclined plane is a simple machine that we use to make our everyday jobs easier, but it will not reduce the total amount of work that must be done. Other machines are sometimes used with the inclined plane to further expand man's ability to accomplish a task!

The activities included in Unit 2 are:

P-7	HEAVE-HO (Work)
P-8	WHAT'S THE ANGLE (The Inclined Plane)
P-9	STEPPING UP (Work expended walking up stairs)
P-10	IT'S ABOUT TIME (Power developed running up stairs)
P-11	HOW HORSE POWER BECAME HORSEPOWER (The story of James Watt developing the steam engine)
P-12	GOING MODERN (Measuring horsepower)

TEACHER RESOURCE



Teacher Resource
page 2

1. An inclined plane is a flat surface raised at one end.

2. An inclined plane makes it possible to apply a small force over a greater distance, so that the total amount of work of exerting a large force through a short distance remains the same.

3. The forces acting on the resistance are balanced when the resistance is not moving. Work is equal to force times the distance the force moves. When the resistance is not moving the distance is 0.

4. The formulas for mechanical advantage are:

$$\text{A.M.A.} = \frac{\text{Actual weight or resistance (W)}}{\text{Effort force (E)}} \qquad \text{(Actual M.A.)}$$

$$\text{I.M.A.} = \frac{\text{Length of plane (De)}}{\text{Height of plane (Dr)}} \qquad \text{(Ideal M.A.)}$$

5. Friction will account for a small experimental error.

6. In the laboratory activity an angle of 30° will be used.

$$\text{M.A.} = \frac{2}{1} = 2$$

Topic 1 - Work is the product of the force times the distance the force moves.

The concept of 'work' and the 'machine' must be developed to understand the inclined plane. Think of the human body as a machine.

MR. MACHINE, CAN YOU DO ANY WORK? (Discussion). WHAT IS WORK? (Discussion). CAN YOU DO WORK WITHOUT EXERTING A FORCE? (Discussion).

Should the question of mental fatigue arise, limit the discussion to physical rather than biological measurements.

DO YOU HAVE TO MOVE SOMETHING TO GET WORK DONE? Yes. (Discussion). WE HAVE AGREED THAT BOTH FORCE AND DISTANCE ARE NECESSARY TO DO WORK. SCIENTISTS SAY WORK IS FORCE TIMES DISTANCE THE FORCE MOVES.

Write on overhead projector "Work = Force times Distance." SO LET'S DO SOME WORK. (Instruct a student to push on a wall.) IS HE DOING ANY WORK? No. (Discussion). WHY? (Discussion). SOMEBODY DRAG A CHAIR. (Do not let the student carry the chair). (While dragging the chair), IS THE CHAIR DRAGGER DOING ANY WORK? Yes.(Discussion) WHY? (Discussion) HOW MUCH FORCE WAS EXERTED? (To determine the force, drag the chair with a large spring balance. Remember that this force must be measured in a horizontal direction only. Any vertical force component would tend to lift the chair, not drag it.)

Have several students measure the distance the chair was dragged. Calculate the work using the overhead projector. Do other experiments if requested.

TEACHER DIRECTION

P - 7

HEAVE - HO

(Work)

Materials for groups of three:

1. Ruler

Materials for the class:

1. Bathroom scale
2. Large spring balance

Let the students complete the table by performing the operations requested in the table. Let them use their imagination in determining how to weigh the various objects.

Using the overhead projector and transparency P-7, calculate and record the data needed to complete the chart for P-7. The first three problems will show a definite relationship as the weight remains the same and the distance increases by one. The work will increase as the distance increases while the weight remains the same.

The term foot-pounds is introduced at this point and should be used freely in the discussion. Try to get the students to use the term, but do not force its use. Explain that foot-pounds is the unit in which work is measured: it is appropriate and makes sense since you multiply distance in feet times weight in pounds. Note that all formulas are written out. Past experiences with formulas have shown that the only symbol which one can use successfully with these students is the equal (=) sign.

LET'S COMPLETE THE CHART TOGETHER, IF YOU HAVE ALREADY COMPLETED YOURS, CHECK YOUR RESULTS.

Ask the weights of the books at random and list one of the answers in the weight column, then solve the problem on the side of the transparency. Explain every step to the students. It is suggested you work the first problem with everyone paying attention, then ask the students to get out scratch paper and work the remaining problem with you. This is a good place to check the students' mathematics. Be sure to verbally recognize success whenever possible.

LET'S LOOK AT THE FIRST NUMBERS IN THE WORK COLUMN AND THE FIRST NUMBERS IN THE DISTANCE COLUMN. CAN YOU SEE ANY TRENDS? (Discussion). As the distance increase, the amount of work increases.

The relation of force, weight and work should be pretty well understood. Play the "Would you believe" game. "WOULD YOU BELIEVE", THAT IF A MAN WEIGHS 150 POUNDS, AND IS LIFTED 2 FEET, THAT THE WORK DONE WOULD BE 300 FOOT-POUNDS. Yes. Solicit problems from the class.

"WOULD YOU BELIEVE, THAT IF THE AMOUND OF WEIGHT INCREASED AND THE DISTANCE MOVED INCREASED, THE AMOUNT OF WORK WOULD INCREASE. (Discussion). Solicit verbal work problems as above from the class.

STUDENT

P - 7

HEAVE - HO

Materials for groups of three:

1. Ruler
2. Spring balance, large

A single word can have meanings and can be used in many different ways. A good example is the word "cut". It can mean turn, such as "cut the corner", or it can mean stop when you say "cut it out", or it can mean slice when you say "cut the butter". Scientists long ago recognized this problem and realized that something had to be done so that scientists everywhere would know what they meant when they used important words such as work.

Technically the word "work" is defined as "force times distance the force moves". This means that a force must be used to move an object some distance. If an object is not moved, then no work has been done.

Complete the table below by filling in the columns left blank. Remember the force is measured with the spring balance, or the bathroom scales. Lift all objects straight up and measure the distance lifted.

WORK

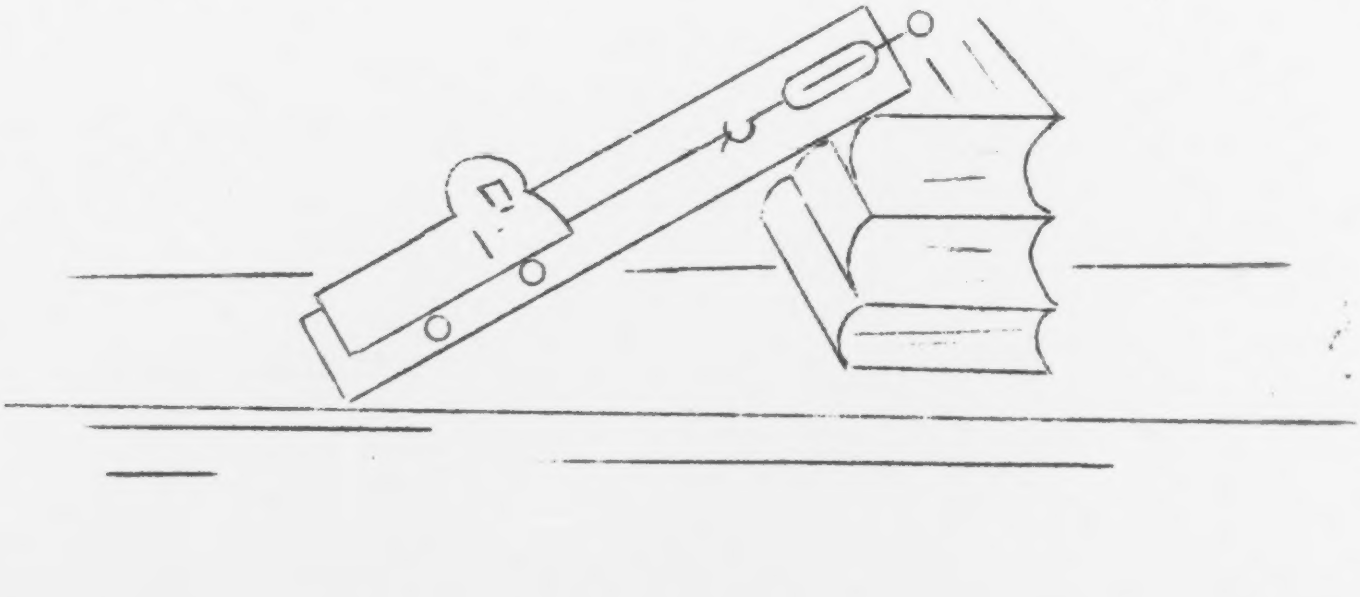
OBJECT	DISTANCE FEET	FORCE pounds	WORK foot-pounds
1 book	1 foot		
1 book	2 feet		
1 book	3 feet		
2 books	2 feet		
2 books	4 feet		
1 shoe	2 feet		
1 shoe	4 feet		
1 chair	1 foot		

Would it take more or less work to lift 10 pounds 2 feet than to lift 20 pounds 2 feet? Why? How much?

Topic 2 - The inclined plane is a flat surface raised at one end.

MANY TIMES THE TERM "FORCE" IS USED TO MEAN WEIGHT. WE CAN DETERMINE FORCE BY USING SCALES OR SPRING BALANCES AS YOU DID IN THE LAST ACTIVITY. BUT WE HAVE LOOKED AT ONLY TWO KINDS OF FORCES, THE EFFORT FORCE AND THE RESISTANCE FORCE. WHAT IS THE DIFFERENCE IN THE TWO FORCES? (Discussion).

The discussion should be very clear regarding the relation of the effort force and the resistance force. The resistance force is related to the resistance, and the effort force is related to the effort. It should also be brought out that the resistance force acts in a direction opposite to the effort force. This will be very important in understanding the inclined plane. Friction should be discussed. Stress that friction should many times be reduced before using a machine to do work. However you would not want to always reduce friction. Consider the following examples. You would not grease pulley force that carry belts to drive other pulleys. Similarly, you would not reduce the friction between the tracks of a bulldozer and the ground. In the following activities, friction will account for some of the experimental error.



LET'S THINK OF SOME WAYS THAT THE EFFORT FORCES MAY BE REDUCED TO MAKE IT EASIER TO LIFT SOME OBJECT OR RESISTANCE. (Discussion). Levers will be mentioned but tell the students to try to think of another way. If the inclined plane is not suggested, give an example of how a man on a wheel chair gets into a house by building a ramp or inclined plane. A car going up a hill is another example.

IF A ROAD BUILDER WAS BUILDING A ROAD IN THE DESERT AND WANTED TO BUILD A BRIDGE OVER A RAILROAD TRACK, HOW COULD HE DO IT? (Discussion). Make the point that the flat surface of the road would be raised to form an inclined plane.

TEACHER DIRECTION P - 8

WHAT'S THE ANGLE

(Inclined Plane)

Materials for groups of three:

1. Ruler
2. Spring balance
3. Two 4-ounce weights
4. Inclined plane
5. Truck

The teacher should demonstrate the inclined plane and also show how it works using transparency P-8. Then the equipment should be issued for the students to assemble prior to a discussion of the procedures. The students do not record data at this time. A trial run by the students is advisable before they start collecting and recording data. Hall's carriages and other inclined planes may also be used in addition to the toy trucks if interest is adequate.

Advise the student to round-off the numbers representing the forces to the nearest ounce. A demonstration may be necessary by weighing the truck to show

how to round-off its weight. It should also be recognized that the spring balances are inaccurate which will account for some of the experimental errors.

After demonstrating the proper techniques, circulate among the groups helping them to succeed.

After completion of the activity, the students will need to examine their results in a class discussion. Using transparency P-8 (a) solicit results from the students and perform the required calculations.

Stress the point that, disregarding friction, the amount of input work is the same as the amount of output work. Even though the amount of work is the same, the effort force and distance varies.

"WOULD YOU BELIEVE", THAT A BOY RUNNING TO THE TOP OF A BRIDGE WOULD DO THE SAME AMOUNT OF WORK BY CLIMBING A LADDER TO THE TOP OF THE BRIDGE. Yes. It may be helpful to make a drawing of the inclined plane on the overhead projector. Some numbers may be needed (whole, simple numbers). Using the weight of one of the students may develop interest. Solicit and use problems from the class.

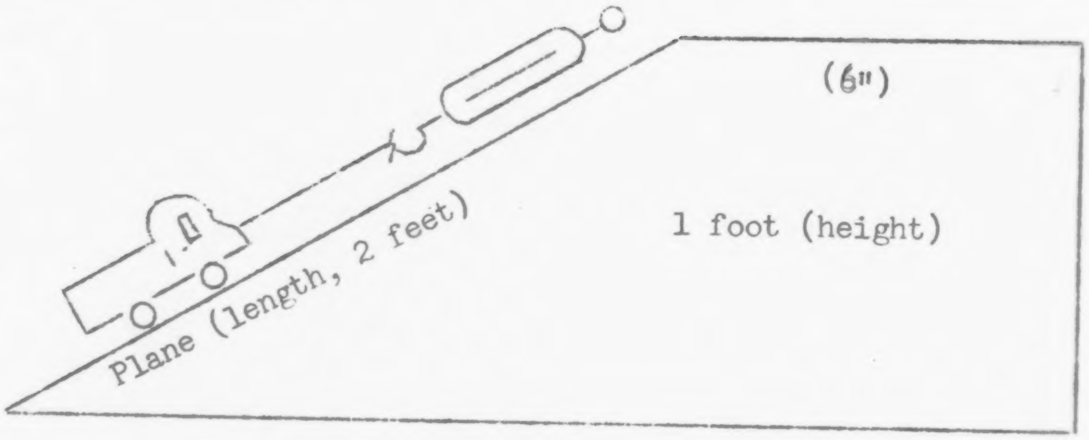
STUDENT

P - 8

WHAT'S THE ANGLE

Materials for groups of three:

1. Ruler
2. Spring Balance
3. Two 4 ounce weights
4. Inclined
5. Truck



To a road builder and the driver of a car, the inclined plane is very important. To make the inclined plane, the road builder raises the flat surface of the road on one end. This makes an incline for cars to be driven up. As you know the steepness of a hill, or its incline, determines how hard it will be for the car to climb the hill. A very steep hill may be too difficult for a car with low horsepower to climb, or it may be so hard to climb that traffic will move slowly near the top of the hill.

As you know, when you are moving something you are doing work. You can find out how much work you are doing by multiplying the effort force, measured on the spring balance, times the distance the object is moved, in this case the length of the plane. Remember that the force and the distance the force acts are in the same direction. Work = effort force times the length of the plane. And of course work is also equal to the resistance force times the distance the object is lifted. This is another way to get the can to the top of the hill. This gives you two ways to measure work. Let's find out if the work you do in pulling the truck up the inclined is equal to the work you do in lifting the truck the height of the plane. Is the effort force times the length of the plane, the same as the resistance force times the height of the plane?

Obtain an inclined plane and the other materials needed to find the answer to the question: Is the effort force times the length of the plane equal to the resistance force times the height of the plane? Gather data and complete the table below by filling in the spaces left blank.

I. Work = Distance lifted (straight up) TIMES Resistance force (weight)

II. Work = length of inclined plane TIMES Effort force (spring balance, pulling up the incline parallel to the inclined surface.)

Work: The Inclined Plane

OBJECT	DISTANCE height	RESISTANCE FORCE	WORK ft. - oz.	LENGTH plane	EFFORT FORCE	WORK ft. - oz.
Truck	1 foot	4 ounces		2 feet		
Truck and 1 weight	1 foot	8 ounces		2 feet		
Truck and 2 weights	1 foot			2 feet		

Is the amount of work the same in both case I and case II for the same object? If not, you need to check your work.

Try other objects if you want to.

TEACHER DIRECTION

P - 9

STEPPING UP

(Effort expended walking up stairs)

Materials for the class:

1. Bathroom scales
2. 50 feet tape measure

The teacher should develop the idea that stairways are good examples of inclined planes. This may be presented by suggesting that notches are cut out of an inclined plane to make stairs. Steps are built for the convenience and safety of the people using them. Since the top of the stairs is higher than the bottom, it meets the definition of the inclined plane, that is, a relatively flat surface raised at one end.

"WOULD YOU BELIEVE," THAT A STAIRWAY IS AN EXAMPLE OF AN INCLINED PLANE? (Discussion). WHY? (Discussion).

SINCE WE KNOW THAT A FLIGHT OF STAIRS IS AN EXAMPLE OF AN INCLINE PLANE, WOULD YOU BELIEVE THAT A BOY RUNNING TO THE TOP OF THE STAIRS WOULD DO THE SAME AMOUNT OF WORK BY CLIMBING A LADDER TO THE TOP OF THE STAIRS, IF THE LADDER IS STRAIGHT UP? Yes. (Discussion). LET'S USE THIS KNOWLEDGE TO FIND THE EFFORT WE USE TO CLIMB A FLIGHT OF STAIRS.

Pass out P-9, page 1.

This activity will require your class to move to an appropriate flight of stairs where the resulting noise will not disturb others. The suggested assignments as outlined on the student activity sheet may require some changes. Involve as many students in the activity as possible. The data can be recorded on the diagram at the top of page 1 while at the stairs.

Before going to the stairs, place transparency P-9 on the overhead projector for use in discussing the procedures and instructions for the activity. Rounding off the distance to the nearest foot will greatly simplify the calculations.

After gathering data on height and length of stairs and the runners have finished, return to the classroom for calculations to be made on page 2.

Using transparency P-9 (a), complete the table making the calculations required. The runners will need to weigh themselves upon returning to the classroom. Each small group should make calculations of their own. Have a representative from each group weigh himself to use for that group's calculation in determining the effort force required to run to the top of the stiars.

Notice this is the same problem discussed on page 10. The amount of energy required to move from the bottome of the stairs to the top of the stairs is the same regardless of the route taken to get there.

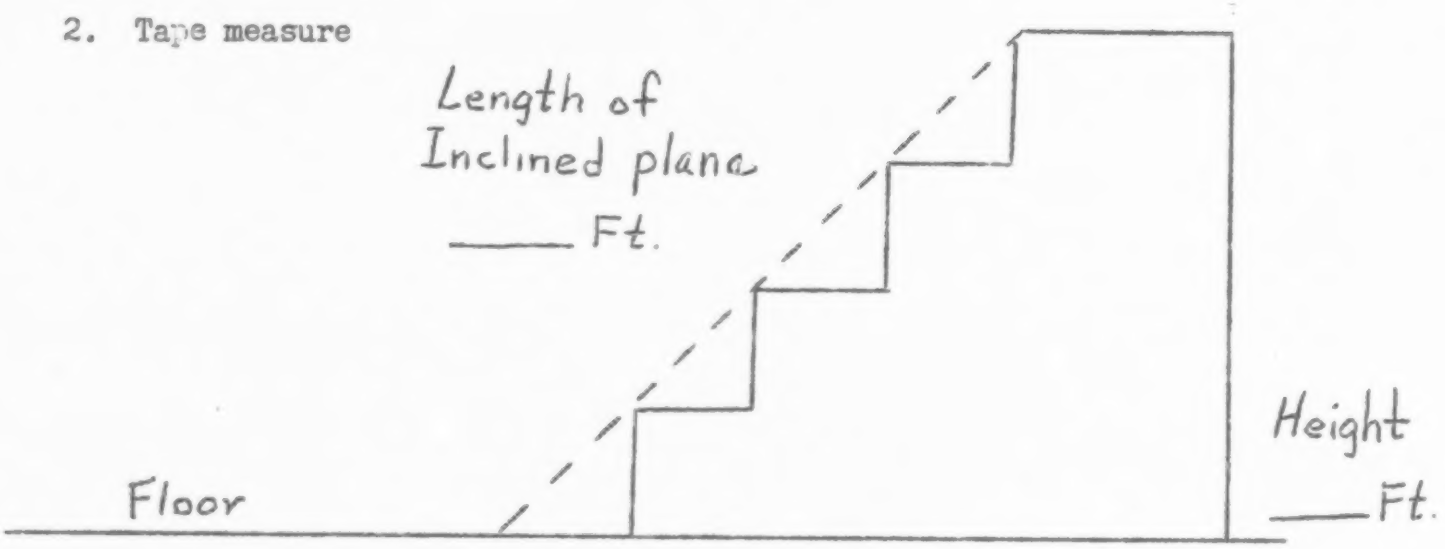
STUDENT

P - 9

STEPPING UP

Materials for the class:

1. Bathroom scales
2. Tape measure



The above drawing is a diagram of some stairs. In this activity, you are to find out how much effort you exert when climbing stairs. It would be very difficult to measure the effort force needed to climb the stairs with a spring balance. So, let's do it another way.

You will need to know the weight of the object to be moved, in this case yourself, and the height you are to move. Remember, the weight of the object (yourself) times the height of the stairs equals the amount of work. So, let's determine the amount of work needed to climb the stairs. First, we will all go to the stairs as directed by your instructor. Each group will be assigned a number.

1. Group 1 measure the height of the stairs.
2. Group 2 also measure the height of the stairs to see if group 1 measured them correctly.
3. Group 3 will record the data for all measurements.
4. Group 4 measures the length of the plane from the floor to the top step.
5. Group 5 will also measure the plane to check on group 4.
6. Group 6 will supply a runner to run up the inclined plane (stairs). The runner will need to weigh himself on bathroom scales when he returns to the classroom. Group 7 should also have a runner.
7. Groups 8, 9, and 10 will be advisors. If any problems arise, these groups will solve them.

Student
page 2

Distance times Resistance = Work

Calculation of Effort

HEIGHT OF STAIRS	RESISTANCE Weight of Runner	WORK Foot-pounds

WORK (From above)	LENGTH OF PLANE Feet	EFFORT FORCE Pounds

Work divided by Length = Effort Force

After completing the above table with your instructor, find out how much effort force is needed for one member of your group to climb the stairs. You should work together as a group on this problem.

HEIGHT OF STAIRS	RESISTANCE Weight of Runner	WORK Foot-pounds

WORK (From above)	LENGTH OF PLANE Feet	EFFORT FORCE Pounds

Topic 3 - Power is the amount of work divided by the time.

TEACHER RESOURCE

$$\text{POWER} = \frac{\text{Distance times force}}{\text{Time}} = \frac{\text{Work}}{\text{Time}} = \frac{\text{foot-pounds}}{\text{Seconds}}$$

$$\text{HORSEPOWER} = \frac{\text{Work}}{550 \times \text{Seconds}}$$

550 is the conversion factor
One H.P. = 550 ft-lb/sec.

WOULD YOU DO AS MUCH WORK WALKING UP THE STAIRS AS RUNNING UP THE STAIRS? Yes. (Discussion). WHY? Work is not a function of time. Power is a function of time.

TELL ME SOMETHING. WHY CAN SOME CARS ACCELERATE FASTER THAN OTHERS EVEN IF THEY WEIGH THE SAME? (Discussion). The term horsepower will be mentioned by the students. WHAT IS HORSEPOWER? (Discussion). HORSEPOWER IS THE AMOUNT OF WORK THAT AN AVERAGE HORSE CAN DO IN A CERTAIN AMOUNT OF TIME. HORSEPOWER IS JUST ONE OF MANY WAYS OF EXPRESSING POWER. SO LET'S TALK ABOUT POWER FIRST AND THEN HORSEPOWER. SCIENTISTS SAY POWER IS THE AMOUNT OF WORK DIVIDED BY THE TIME REQUIRED TO DO THE WORK. FOR INSTANCE, IF YOU LIFTED A 10 POUND SACK OF SUGAR 4 FEET IN 2 SECONDS, HOW MUCH POWER WOULD IT TAKE? (Write the formula on the overhead projector using words not symbols). FIRST, LET'S DETERMINE THE AMOUNT OF WORK. (Calculate the work on the overhead projector using transparency P-10 with the formula for power written on it for the next two items). THIS IS THE AMOUNT OF WORK REGARDLESS OF HOW LONG IT TOOK TO DO THE WORK. (Discussion). NOW, DIVIDE BY THE TIME AND WE HAVE DETERMINED THE POWER. (Discussion). BUT WHAT IF IT HAD TAKEN FOUR SECONDS TO LIFT THE SACK OF SUGAR? HOW MUCH POWER WAS NEEDED? (Discussion). Play the 'would you believe' game soliciting problems from the class.

HOW MUCH POWER DO YOU HAVE? (Discussion). LET'S FIND OUT BY RUNNING UP SOME STAIRS. Pass out P-10.

TEACHER DIRECTION P - 10

IT'S ABOUT TIME

(Power developed running up stairs)

The students are to use the same stairs for this activity as in P-9. Students should be instructed in stop-watch procedures for timing. Give the students numbers representing the height and the length of the plane to write-in on their drawing. Each student is to determine his own power which will require each student to weigh himself. Caution students about running up stairs too fast. Answer all questions, then proceed to the stairs where each group will run up the stairs in a predetermined order. Use descretion in excusing students due to individual personalities. These can be given associated jobs.

After completion of the activity return to the classroom for a class discussion of calculations. Have students (who can) calculate their power prior to the class discussion. You can reinforce the calculation in the large group discussions. A few calculations of individual horsepower will be interesting, but the mathematics is too difficult for most of the students to perform alone. Proceed to the next activity in a short time.

TEACHER DIRECTION P - 11

HOW HORSE POWER BECAME HORSEPOWER

(The story of James Watt developing the steam engine)

Activity P-11 is a reading assignment designed to develop interest in measuring horsepower. The words centuries and Cyldesdale horse (Budweiser's horses are this type) should be explained as the activity sheet is passed out.
Pass out P-11.

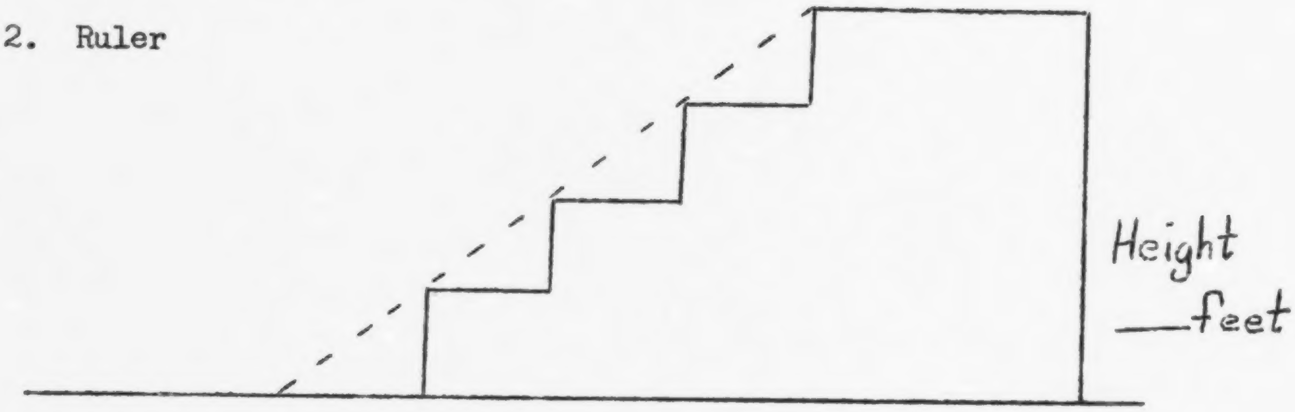
STUDENT

P - 10

IT'S ABOUT TIME

Materials for groups of three:

1. Stop-watch
2. Ruler



Each student is to determine his own power. While one is running up the stairs, another member of the group is to use the stop-watch to time the member. The third member is to stand at the top of the stairs to signal GO and STOP

HEIGHT OF STAIRS	RESISTANCE Weight of runner	WORK foot-pounds

Distance times Resistance = Work

WORK (from above)	TIME seconds	POWER foot-pounds/seconds

Work divided by Time = Power

Are you a very powerful machine?___________________

HOW HORSE POWER BECAME HORSEPOWER

It seems strange that in our age of jet planes and fast automobiles that scientists still measure power the same way they did during the period when horses were the main means of transportation. The history of horsepower is an interesting story. The real story could be called "How Horse Power Became Horsepower" in our world of progress and change.

Man first used simple machines to lift objects by using his own muscles to provide the force needed, but this would not allow him to accomplish all he wanted to accomplish. The wheel, levers, pulleys, as well as any other device he could think of were used, but still man was limited to his own energy. One day a man had an idea about his friendly animal standing next to him. The idea was to use the animal's strength along with his own; so animal power came into being. Through time man realized the horse was a fine animal to produce the force needed to accomplish the work. Many centuries and many hours of work were spent by men and horses in the history of man. The good horse may have been "man's best friend" for a long time, but now man's best friend may be a motor or an engine because the horse cannot compete with the modern day machines..

The beginning of man's use of fuel to develop power has a long and interesting history. An important event was the substitution of Mr. James Watt's mechanical steam engine to replace the faithful old horse. Mr Watt was a Scottish engineer who lived from 1736 to 1819. He realized that steam engines were more powerful than the horse and tried to get coal miners to use the engine instead of horses to lift heavy buckets of coal and other objects. The men to whom Mr. Watt wanted to sell the engines were interested in knowing how many horses the machine would replace. To answer this question, Mr. Watt started a scientific investigation to find out.

Student
page 2

Mr Watt observed two important factors. The first was that man became tired very quickly and therefore could not work at a steady pace. The second observation was that horses worked tirelessly at a steady pace for long periods of time. He decided to compare his steam engine to horses. Mr. Watt used a Clydesdale horse to walk round and round a wheel which was used to raise a 100 pound weight out of a deep well. He found that a horse could work over a long length of time at a speed of about 2½ miles per hour while lifting the weight. The friction of the wheel was 50 pounds, so the horse was really lifting 100 pounds plus overcoming the friction of 50 pounds, or altogether 150 pounds. Mr. Watt knew that the power was equal to the number of feet moved, times the weight, divided by the time. The power of the horse was determined to be 550 foot-pounds per second, or 33,000 foot-pounds per minute. So Mr. Watt said, and everyone agreed, that the power of one horse will not be called horse power, but HORSEPOWER, and that 1 horsepower will equal 550 foot-pounds per second. The term horsepower is still used today as you know, and it really means "horse power". In other words, if your car has a 360 horsepower engine, it is the same power as 360 horses under the hood if you use Clydesdale horses as Mr. Watt did. Do you know why it must be Clydesdale horses?

TEACHER DIRECTION P - 12

GOING MODERN
(Measuring Horsepower)

It is doubtful that the students will understand the calculations of horsepower but with discussion and leading questions the teacher can promote some critical thinking and application. Attempt to get the students to relate this activity to their environment.

The reference for the drawings is Brown and Schwachtgen, Physics: The Story of Energy, Heath and Company, Boston, 1954 pp 178-79. The formula for the calculation of horsepower for the electric motor is:

$$\text{Horsepower} = \frac{\text{Force times the Distance (Circumference)}}{\text{Seconds for 1 turn times 550}}$$

$$= \frac{\text{275 pounds times 2 feet}}{\text{1 second times 550}} = \frac{550}{550}$$

$$= \text{1 horsepower}$$

The distance around the wheel can be measured with a tape measure of ruler or it can be calculated. It is recommended that measuring be stressed and not the calculation of the circumference. Perform the calculations only if the students show adequate interest.

$$\text{Circumference} = \frac{22}{7} \text{ x Diameter}$$

The steam engine should be placed on the teacher's desk one day prior to passing out P-12 to create interest. The students will want to play with the steam engine. Answer the questions asked, but do not start the engine until after the students read P-12.

TEACHER DIRECTION

P - 12

GOING MODERN

After discussing P-12 calculate the horsepower of the steam engine as discussed in the reading. Use a spring balance to determine the effort force. Measure the circumference of the wheel, and determine the time with a stop-watch. This may be done as a class project or in groups, but let the students use the steam engine only after a procedure has been developed in the class discussion. It is important that the students be allowed to use the steam engine, but under direct supervision of the teacher.

All of P-12 should be read with the students aloud after the students have read it silently. The students should follow the reading while the teacher reads aloud. Explain each step and sentence. Encourage discussion at all times.

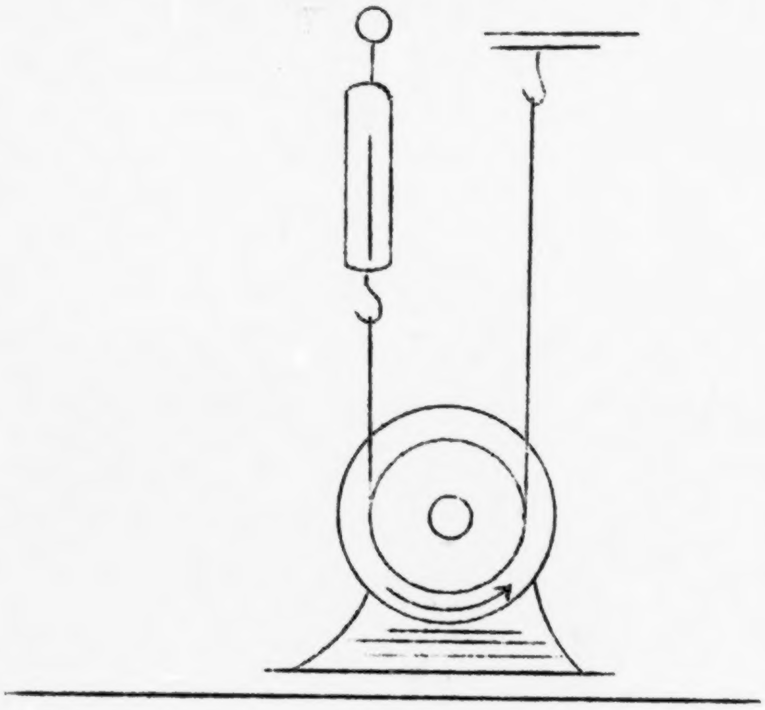
After completion of the activity, if the students wish to bring a bicycle into the classroom or bring motors from home for determination of horsepower, encourage it. For the bicycle, about 1/4 of the student's weight will be the effort force. (The tire on the bicycle wheel moves about 4 times as far as the feet do on the pedals. So the tire would push backwards with a force only 1/4 as great as the weight of the rider). The mechanical advantage of the combined machines in the bicycle is one-fourth. The distance will be the circumference of the rear wheel, and the time will be the number of seconds it takes the student to go the distance of the circumference of the rear wheel. It will be necessary to go outside for this activity. The distance can be marked off by using chalk and then timing individual investigations. Encourage this and pursue all avenues of investigations that are suggested and reasonable. Pass out P-12

STUDENT P - 12

GOING MODERN

We have advanced from the period of using horses to jet engines and rockets. The term horsepower remains the same, however, and science has found no need to change it. Of course, the methods of testing horsepower varies. For example, would you test for horsepower of a jet engine the same way you would test for horsepower of an electric motor? No sir, you would not! How would you test for horsepower of a man? Mr. Watt did this and found an average man to be about one-tenth (1/10) of a horsepower.

The electric motor has a wheel on the end. One way to test for the horsepower is shown in the drawing below.



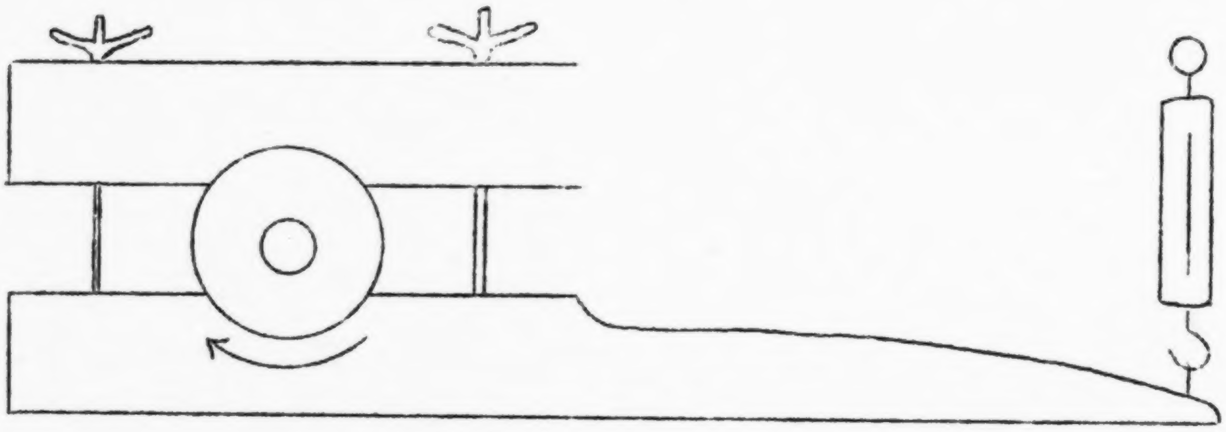
Try to figure out how you could determine the horsepower of the motor in the diagram above. The facts to remember are:

1. The effort force is measured in pounds with a spring balance.
2. The distance traveled will have to be determined from the wheel on the motor by measuring the distance around of the wheel.
3. Time is the number of seconds needed for the wheel to make one complete revolution.

4. One horsepower equals 550 foot-pounds per second.
5. The formula for determining horsepower is:

$$\text{Horsepower} = \frac{\text{Force times distance}}{\text{Seconds times 550}}$$

Another way to determine the horsepower of an engine is to use a "Prony brake" Look at the drawing below and see if you can figure out how it works.



A jet engine is something else. It does not have a wheel that turns, but a strong thrust from the rear of the engine. Could you measure this thrust by placing a set of scales similar to the bathroom scales behind the jet engine to determine the force? Yes sir, you sure could! The distance and time the jet would move would give you all the information needed to determine the horsepower of the jet.

Some of the ways of determining horsepower are listed above on the previous pages. If you will ask your instructor to show you the steam engine, you may be able to determine its horsepower. If you have an electric motor at home or could borrow one, you could also calculate its horsepower.

Isn't it amazing that even in our age of atomic reactors and supersonic jets, the power of a Clydesdale horse is still one of the most important measurements of science?

UNIT 3 THE PULLEY

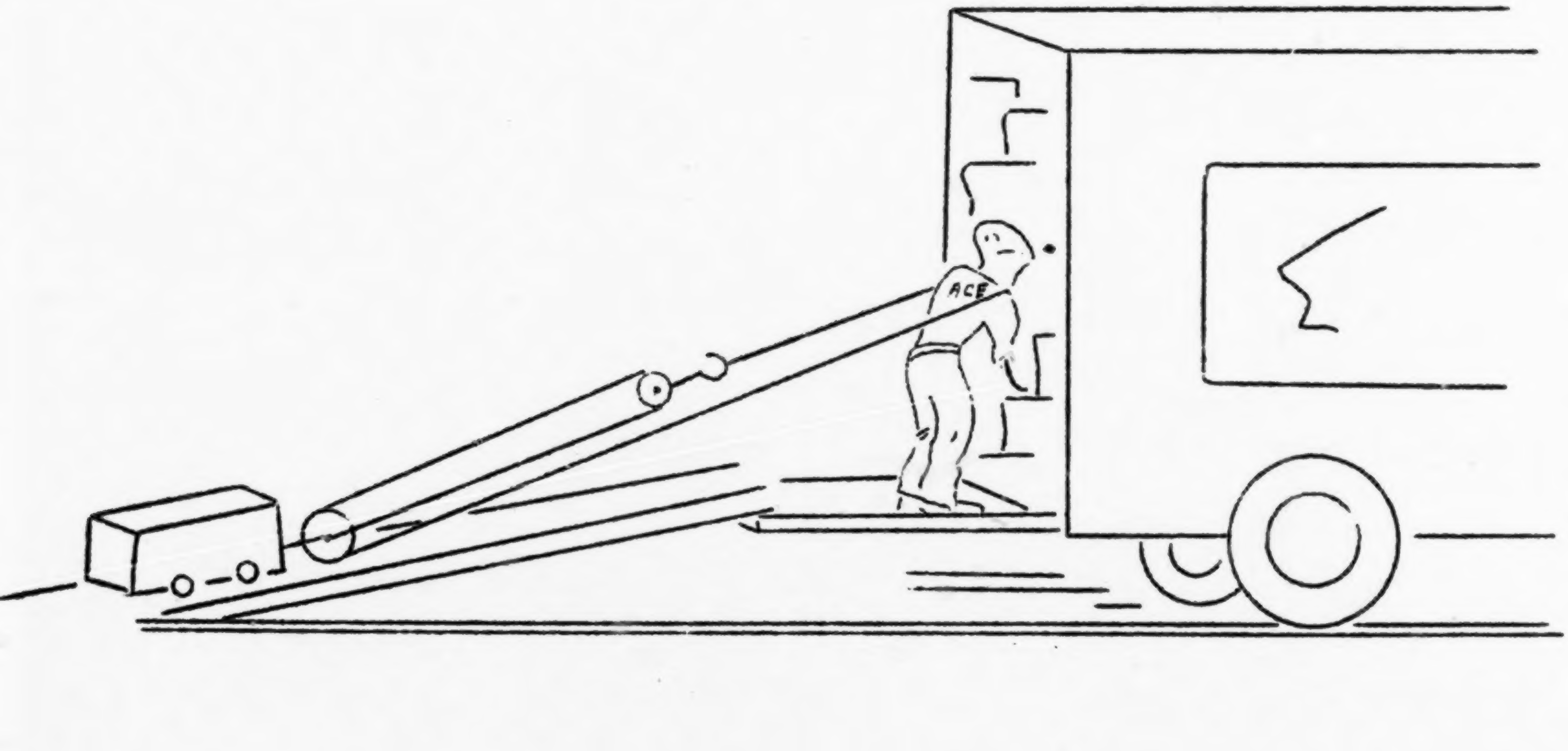
The unit on the pulley contains only three activities but need not be limited to these. Many different systems for many different uses can be demonstrated. The activities are:

P-13 THE SINGLE FIXED PULLEY

P-14 MOVABLE PULLEYS

P-15 COMBINATION OF PULLEYS

Pulleys and pulley systems are often used with other machines, such as the inclined plane or winch (gear box), in order to increase a persons abilities to move heavy objects. This unit will also be concerned with mechanical advantage; how much "easier" it is to do work with the machine. The mechanical advantage of a complex machine (more than one machine combined to do a single task) is equal to the product of the mechanical advantage of each machine.



TEACHER RESOURCE

UNIT 3 THE PULLEY

The term "single fixed pulley" refers to the case where only one pulley rotates about a shaft which is fixed or anchored in place; that is, the shaft is not free to move. Using more than one single fixed pulley only changes the direction in which the effort force must be exerted. The term "single moveable pulley" refers to the case where the shaft is free to move in some direction without reference to rotation. The use of more than one single moveable pulley will not be investigated.

The pulley (as a simple machine) will be investigated with respect to the mechanical advantage of the machine. The mechanical advantage of a single fixed pulley is 1. There will be no change in the ratio of the resistance to effort forces or speeds. The product of the mechanical advantage and effort force will be the resistance force - one time any number gives the number. Therefore, in the case of the single fixed pulley, the resistance force will equal the effort force, neglecting friction.

The mechanical advantage of the single moveable pulley is 2. This can be determined by the work - energy principle which leads us to the following formula. Remember, we are neglecting all frictional forces.

$$\text{M.A.} = \frac{\text{Resistance force or load}}{\text{Effort force}}$$

OR

$$\text{M.A.} = \frac{\text{Distance effort force moves}}{\text{Distance resistance (load) moves}}$$

Mechanical advantage can also be determined by counting the number of supporting lines in a pulley system. If the effort force is being exerted in the direction that the load moves, it should be counted as a supporting line. If it moves in the opposite direction then it should not be counted. Refer to the diagrams on page 10. In the first case, the pulley over which the line supplying the effort force is actually a moveable pulley. In the second case the pulley closest to the effort force line is a fixed pulley and merely changes the direction in which one might apply an effort force.

Topic 1 - The single fixed pulley has a mechanical advantage of 1 and changes direction only. The single moveable pulley has a mechanical advantage of 2 and does not change direction.

The initial discussion of pulleys should introduce and define the pulley. The students probably have seen many pulleys before in the form of a block and tackle on boats or as a single pulley on a flag pole. Considerable time for assembly of apparatus and completion of the activity will be required since the students have not used the apparatus before. Use your judgement in determining whether the actual experimentation should proceed on the same day as the initial discussion. Use an assembled model along with transparency P-13 as a demonstration.

HOW MANY OF YOU HAVE EVER SEEN ROOFERS SPREADING TAR ON A ROOF? (Discussion) HOW DID THEY GET THE TAR FROM THE GROUND TO THE TOP OF THE ROOF? (They pulley will probably be mentioned. If not, ask about getting water out of a well, or how a crane operates). YOU HAVE SAID THAT A PULLEY IS USED IN LIFTING SOMETHING. LET'S DRAW A PULLEY. Instruct the students to draw a simple pulley on a piece of paper. Perhaps some student can prepare an acetate for you or draw a picture of a pulley on the overhead projector. Pointing at the wheel on the drawing, LET'S CALL THIS A WHEEL.. Then pointing at the axle, LET'S CALL THIS AN AXLE. SO, A PULLEY IS A WHEEL THAT WILL TURN ON AN AXLE. (Discussion) This definition will open many areas of discussion, accept all answers that meet the criteria. A pulley does not have to be a laboratory apparatus, but a machine.

This is a good time to stop if time is running short. If time did run out, a review of the pulley and its definition using an assembled model should be presented before continuing.

OUR ROOF DOESN'T NEED REPAIRING AND WE DON'T HAVE A CRANE TO WORK WITH, BUT WE DO HAVE SOME SMALL PULLEYS THAT WE CAN MAKE MODELS WITH TO INVESTIGATE AND FIND OUT HOW THEY WORK. SO, LET'S GO TO WORK.

Pass out the first page P-13.

TEACHER DIRECTION

P - 13

THE SINGLE FIXED PULLEY

Materials for groups of three:

1. 1 hardboard
2. 2 slotted hardboard supports
3. 1 plastic tube
4. 2 pulley wheels
5. 2 bolts, 1½ inches long
6. 2 brass spacers
7. 2 nuts
8. 2 wing nuts
9. 1 lead weight
10. 1 cord, 36 inches long
11. 1 spring balance

Instruct the students to set up the apparatus as shown in the diagram on their activity sheet following the directions below the picture. The teacher should circulate among the groups offering assistance where needed or requested. The students are not to begin the actual experimentation until all have assembled their apparatus and the procedure discussed.

Note that a single fixed pulley is to be mounted in the lower right corner of the hardboard. This pulley will be used for ease of measurement. The spring balance must be supported in an upright position for all measurements. Otherwise, the weight of the spring balance **will be included** in the reading.

After all have assembled their apparatus, pass out the second page of P-13. Place transparency P-13 on the projector.

FIRST, LET'S WEIGH THE LEAD WEIGHT ON THE SPRING BALANCE AS SHOWN IN THE FIRST DIAGRAM. HOW MUCH DOES IT WEIGH? (Pause) RECORD THIS WEIGHT IN THE BLANK BESIDE THE PICTURE.

NOW, LOOP THE STRING OVER THE PULLEY AS SHOWN IN THE SECOND DIAGRAM AND RECORD THE WEIGHT FROM THE SPRING BALANCE. (Pause) YOU WILL HAVE TO STAND UP-SIDE-DOWN TO READ THE SCALE. IS IT MORE OR LESS THAN THE WEIGHT OF THE LEAD WEIGHT? More.

You will need to remind the students that they are to take the readings while gradually pulling on the string. The movement of the lead weight should be a smooth and a constant rate.

NOW, LOOP THE STRING AROUND THE BOTTOM PULLEY AS SHOWN IN THE THIRD DIAGRAM. GRADUALLY LIFT THE SPRING BALANCE AND READ THE WEIGHT WHILE THE LEAD WEIGHT IS MOVING UP. (Pause). NOW, GRADUALLY LOWER THE SPRING BALANCE AND READ THE WEIGHT WHILE THE LEAD WEIGHT IS MOVING DOWN. (Pause). WHAT IS THIS WEIGHT? WHAT IS THE AVERAGE OF THE UP AND DOWN WEIGHTS? (Pause). RECORD THIS AVERAGE WEIGHT IN THE BLANK BESIDE THE THIRD DIAGRAM. Explain to the students that this procedure is necessary to eliminate the error due to friction. Only the average weight is used.

HOLDING THE BALANCE UP-SIDE-DOWN BY THE HOOK, READ THE SCALE. HOW MUCH DOES THE SPRING BALANCE WEIGH? (Pause). RECORD THIS WEIGHT BESIDE THE FOURTH DIAGRAM.

The students should keep the apparatus in front of them while discussing the results. HOW MUCH DOES THE LEAD WEIGHT WEIGH? (Discussion). HOW MUCH IS ITS AVERAGE WEIGHT AS SHOWN IN THE THIRD DIAGRAM? (Discussion). IT WEIGHS ABOUT THE SAME, DOESN'T IT? THE PULLEY DOESN'T HELP US MUCH THEN, ACCORDING TO THESE DATA. (Discussion). HOW MUCH DOES THE LEAD WEIGHT WEIGH IN THE SECOND CASE WHERE THE WEIGHT OF THE BALANCE WAS INCLUDED? Pause. Weight recorded in the last diagram. IF YOU SUBTRACT THE WEIGHT OF THE SPRING BALANCE FROM THE WEIGHT YOU RECORDED IN THE SECOND DIAGRAM WHEN YOU LOOPED THE STRING OVER ONLY ONE PULLEY, HOW MUCH WOULD THE LEAD WEIGH? (Discussion) HOW DOES THIS COMPARE WITH THE WEIGHT OF THE LEAD WEIGHT IN PART 1? (Discussion). THE WEIGHTS ARE ABOUT THE SAME. THE DIFFERENCE IS SO SMALL THAT WE CAN BLAME IT ON FRICTION. (Discussion).

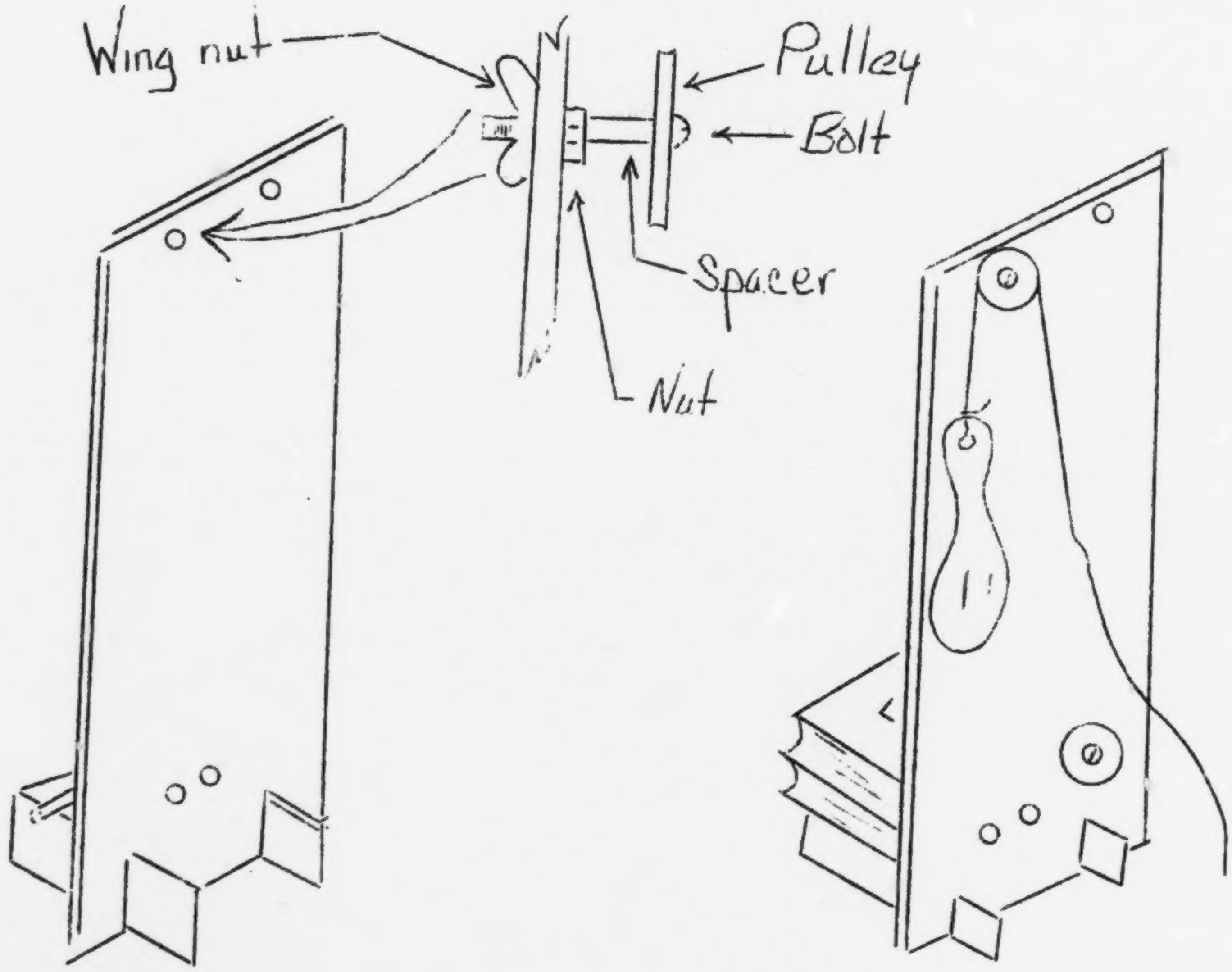
SO WE SEE THAT A FIXED PULLEY ONLY CHANGES DIRECTION. WE MUST PULL ON THE ROPE IN A DIRECTION OTHER THAN THE DIRECTION THE RESISTANCE MOVES. HOW DO WE USE THIS MACHINE TO HELP US DO WORK. (Discussion). The teacher should emphasize the point that the single fixed pulley only changes direction and does not increase the speed or decrease the force needed to move objects.

Instruct the students to disassemble the apparatus and return it to its proper place.

STUDENT

P - 13

THE SINGLE FIXED PULLEY



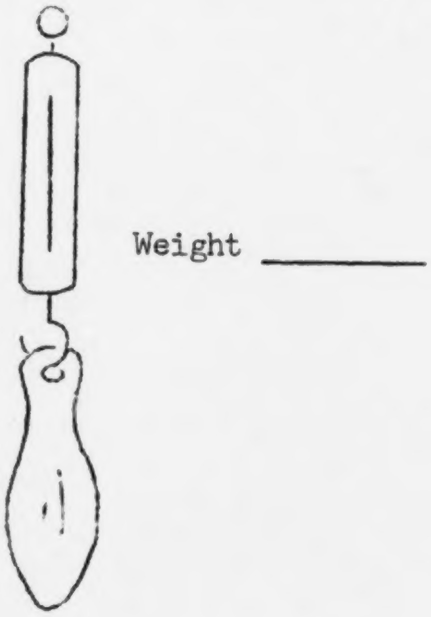
Materials for groups of three:

1. 1 hardboard
2. 2 slotted hardboard supports
3. 1 plastic tube
4. 2 pulley wheels
5. 2 bolts, 1½ inches long
6. 2 brass spacers.
7. 2 nuts
8. 2 wing nuts
9. 1 lead weight
10. 1 cord, 36 inches long
11. 1 spring balance

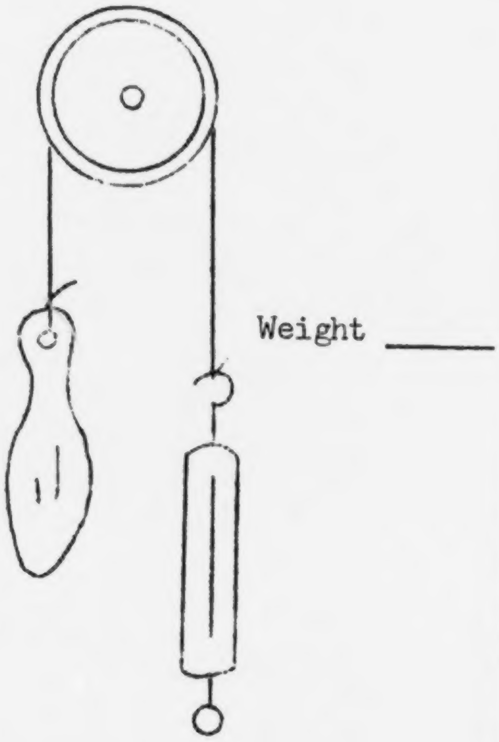
Assemble your apparatus as shown in the diagrams above. The hardboard will need to be placed on the edge of your desk and a couple of books placed on the supports behind the board for added support. The nut next to the spacer should be loose enough so that the pulley wheel will turn freely but not wobble. Follow your instructor's instructions. When everyone has finished, you will receive another sheet of paper to complete the experiment.

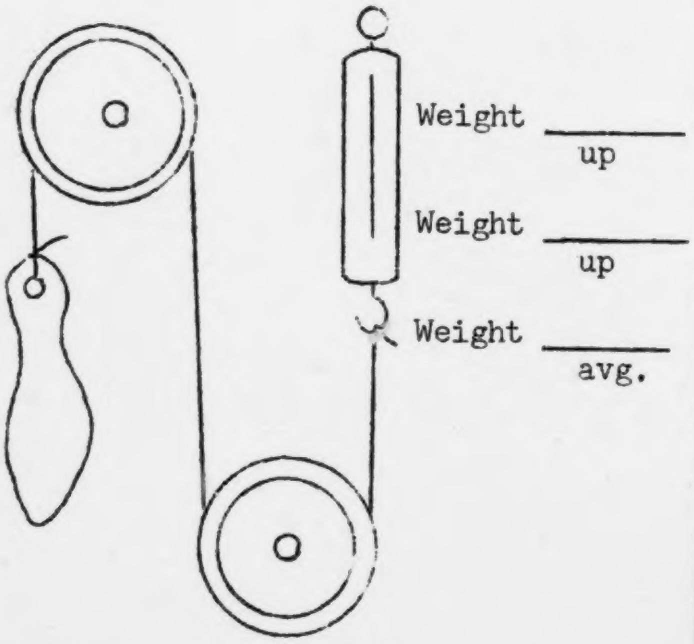
Student
page 2

No. 1

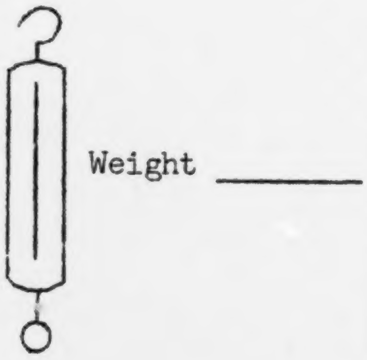


No. 2




Weight ______
up
Weight ______
up
Weight ______
avg.

No. 3



No. 4

TEACHER DIRECTION

P - 14

MOVEABLE PULLEYS

Materials for groups of three:

1. 1 hardboard
2. 2 slotted hardboard supports
3. 1 plastic tube
4. 1 pulley block
5. 2 pulley wheels
6. 3 bolts, $1\frac{1}{2}$ inches long
7. 1 hook
8. 3 brass spacers
9. 3 nuts
10. 3 wing nuts
11. 1 lead weight
12. 1 cord, 42 inches long
13. 1 spring balance

A review of P-13 should be presented using an assembled apparatus emphasizing that the fixed pulley only changes the direction the effort force must be exerted. No gain in speed or force is realized. Also point out that the distance the resistance force had to move was equal to the distance the effort force moved, therefore, no gain in distance.

Pass out the first page of P-14

Instruct the students to set up the apparatus as shown in the diagram on their activity sheet. This is similar to the previous exercise and should not take long. A quick tour through the room will reveal any difficulties. After all have assembled their apparatus, pass out page 2 of the activity for the actual experimentation. Place transparency P-14 on the projector.

THE FIRST TWO PARTS OF THIS ACTIVITY WILL BE THE SAME AS THEY WERE IN THE LAST ACTIVITY. LOOK AT THE FIRST DIAGRAM ON YOUR PAPER. WHAT IS THE WEIGHT OF THE LEAD WEIGHT? (Pause). IS IT THE SAME AS IT WAS THE LAST TIME YOU WEIGHED IT? RECORD THIS WEIGHT IN THE BLANK BESIDE THE DIAGRAM (Pause). Record the weight on the transparency.

NOW LOOK AT THE SECOND DIAGRAM WHERE THE STRING IS LOOPED AROUND THE FIXED PULLEY AT THE TOP AND BOTTOM OF THE HARDBOARD. (Indicate on the transparency). WHAT IS THE WEIGHT OF THE LEAD WEIGHT IN THIS CASE? REMEMBER, YOU HAVE TO MOVE THE WEIGHT

UP AND DOWN AND RECORD THE AVERAGE OF THESE TWO READINGS. Pause. IS THE WEIGHT THE SAME AS IT WAS BEFORE? (Pause). Discussion should reinforce the idea that there is no reduction in effort force.

LOOK AT THE THIRD DIAGRAM. NOTICE THAT ONE END OF THE STRING IS ATTACHED TO THE HOOK AT THE TOP, LOOPED THROUGH THE MOVABLE PULLEY, AND THEN SUPPORTED BY THE SPRING BALANCE. THE LEAD WEIGHT IS ATTACHED TO THE MOVABLE PULLEY. SET UP YOUR APPARATUS LIKE THIS, AND READ THE SPRING BALANCE. (Pause). WHAT IS THE SPRING BALANCE READING NOW? RECORD THIS READING IN THE BLANK BESIDE THE DIAGRAM. (Pause). HOW DOES THIS WEIGHT COMPARE TO THE WEIGHT OF THE LEAD WEIGHT IN THE FIRST DIAGRAM? (Discussion) THE LEAD WEIGHT, WHICH WE COULD CALL THE RESISTANCE FORCE, IS TWICE THE EFFORT FORCE, ISN'T IT? (Discussion). THE LEAD WEIGHT IS NOW BEING SUPPORTED BY TWO SPRINGS RATHER THAN ONE. ANY ADVANTAGE WE GAIN WHEN WE USE A MACHINE TO MAKE OUR WORK EASIER IS GIVEN A SPECIAL NAME, MECHANICAL ADVANTAGE. THE MECHANICAL ADVANTAGE OF THE PULLEY IN THE THIRD DIAGRAM IS 2. THIS MEANS THAT WE CAN LIFT A WEIGHT WITH THE MACHINE THAT IS TWICE AS "HEAVY" AS THE EFFORT FORCE WE APPLY. WE CAN ALSO TELL THE MECHANICAL ADVANTAGE BY COUNTING THE NUMBER OF STRINGS WHICH SUPPORT THE RESISTANCE. (Pause for discussion and explanation).

THE MECHANICAL ADVANTAGE OF THE PULLEYS IN THE SECOND DIAGRAM WHERE YOU HAD ONLY FIXED PULLEYS WAS 1. CAN YOU TELL WHY? (Discussion). THE MECHANICAL ADVANTAGE OF ANY FIXED PULLEY WILL BE 1. (Discussion). Hint: Count the number of supporting string(s).

LET'S LOOK AT THE FOURTH DIAGRAM. HERE THE STRING IS ATTACHED TO THE HOOK, LOOPED THROUGH THE MOVEABLE PULLEY, OVER THE FIXED PULLEY AT THE TOP, AND UNDER THE FIXED PULLEY AT THE BOTTOM. SET UP YOUR APPARATUS LIKE IT IS IN THE DIAGRAM AND RECORD THE READING FROM THE SPRING BALANCE. REMEMBER, YOU MUST MOVE THE WEIGHT UP AND DOWN, AND RECORD THE AVERAGE OF THE READINGS. (Pause for experimentation).

WHAT MECHANICAL ADVANTAGE DID YOU RECORD? (Pause). HOW DO YOU KNOW? (Discuss)

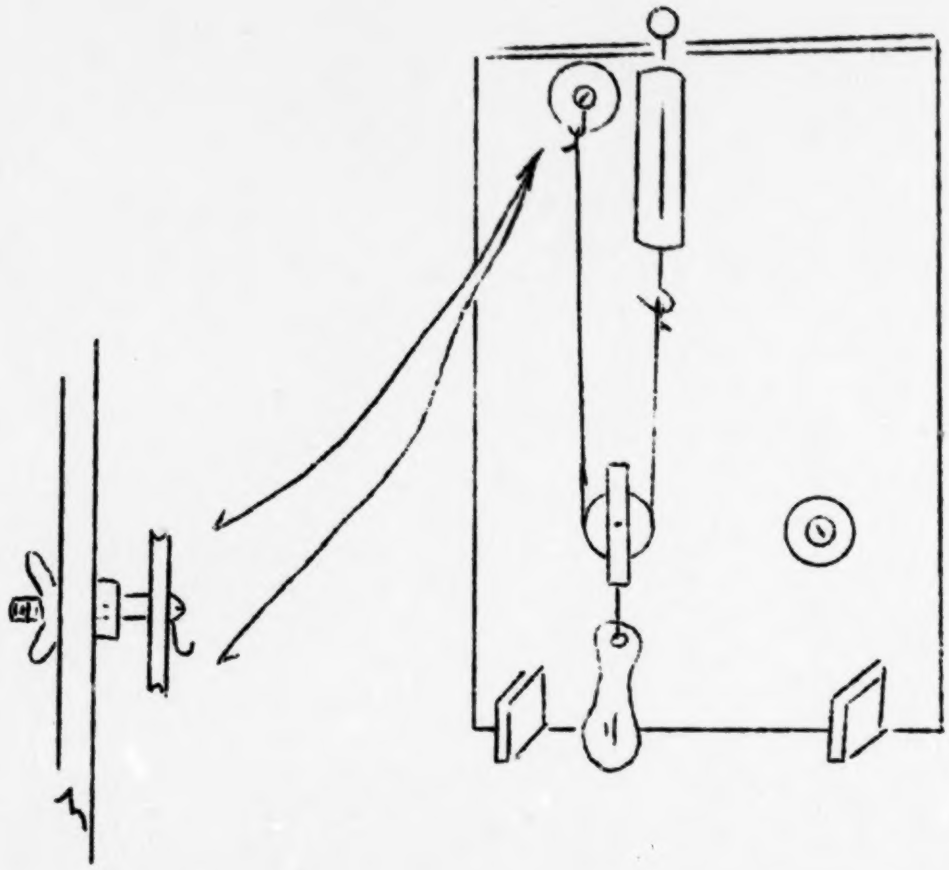
Time will probably run out. If some time is left, let the students experiment on their own. Instruct them to disassemble their apparatus and return it at the end of the period.

STUDENT P - 14

MOVEABLE PULLEYS

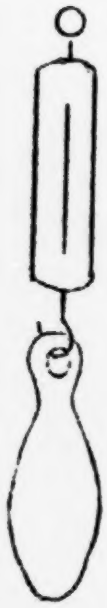
Materials for groups of three:

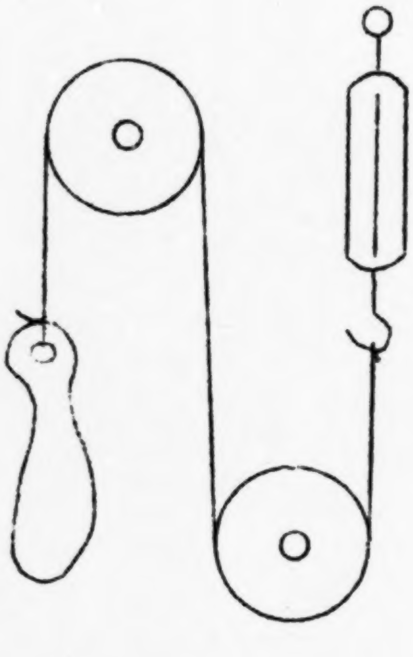
1. 1 hardboard
2. 2 slotted hardboard supports
3. 1 plastic tube
4. 1 pulley block
5. 2 pulley wheels
6. 3 bolts, 1½ inches long
7. 1 hook
8. 3 brass spacers
9. 3 nuts
10. 3 wing nuts
11. 1 lead weight
12. 1 cord, 42 inches long
13. 1 spring balance

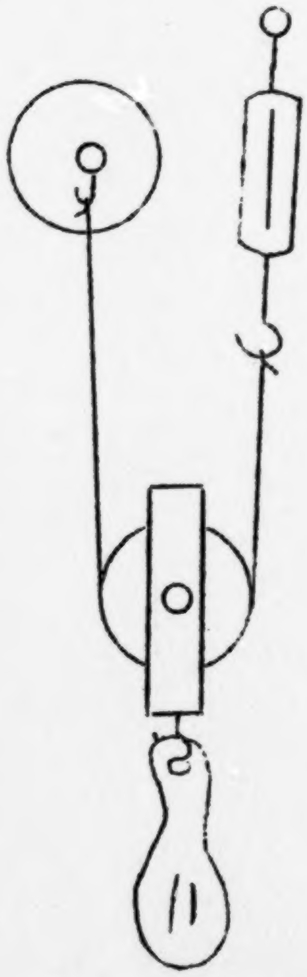


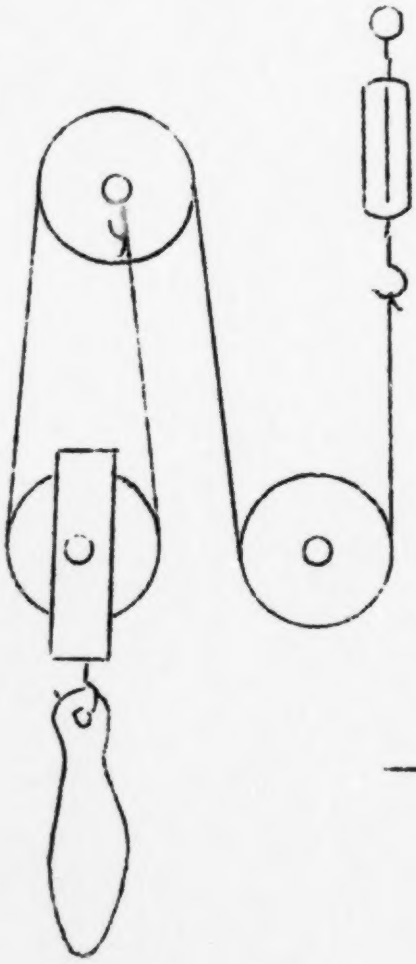
Set up your apparatus the same as you did in the last activity. Refer to the diagram above. After completion, your instructor will give you the second page of the activity for experimentation.

Student
page 2









Topic - Combinations of moveable pulleys have mechanical advantages of 2 or more.

TEACHER DIRECTION P - 15

COMBINATIONS OF PULLEYS

Materials for groups of three:

1. 1 hardboard
2. 2 slotted hardboard supports
3. 1 plastic tube
4. 1 pulley block
5. 3 pulley wheels
6. 2 bolts, 1½ inches long
7. 2 brass spacers
8. 2 nuts
9. 2 wing nuts
10. 1 lead weight
11. 1 cord, 48 inches long
12. 1 spring balance

A short review of P-14 using the overhead projector should be used to introduce this activity. Emphasize the concept of mechanical advantage and review methods of determining the M.A. of a pulley system.

Instruct the students to assemble their apparatus as indicated in the first page of their activity sheet. Note the addition of the second fixed pulley at the top. After they have assembled their apparatus, have them proceed on their own to determine the mechanical advantage of the machine. Circulate among the groups offering assistance where needed. Allow sufficient time to complete the activity and also suggest that they devise experiments of their own. Collect the materials near the end of the period leaving only a short time for discussion.

The final discussion should take the form of a question and answer session allowing the students to tell about the experiments they did on their own.

The next unit is on friction. The need to investigate the nature of friction, ways to reduce it, and friction as a source of experimental error should be mentioned.

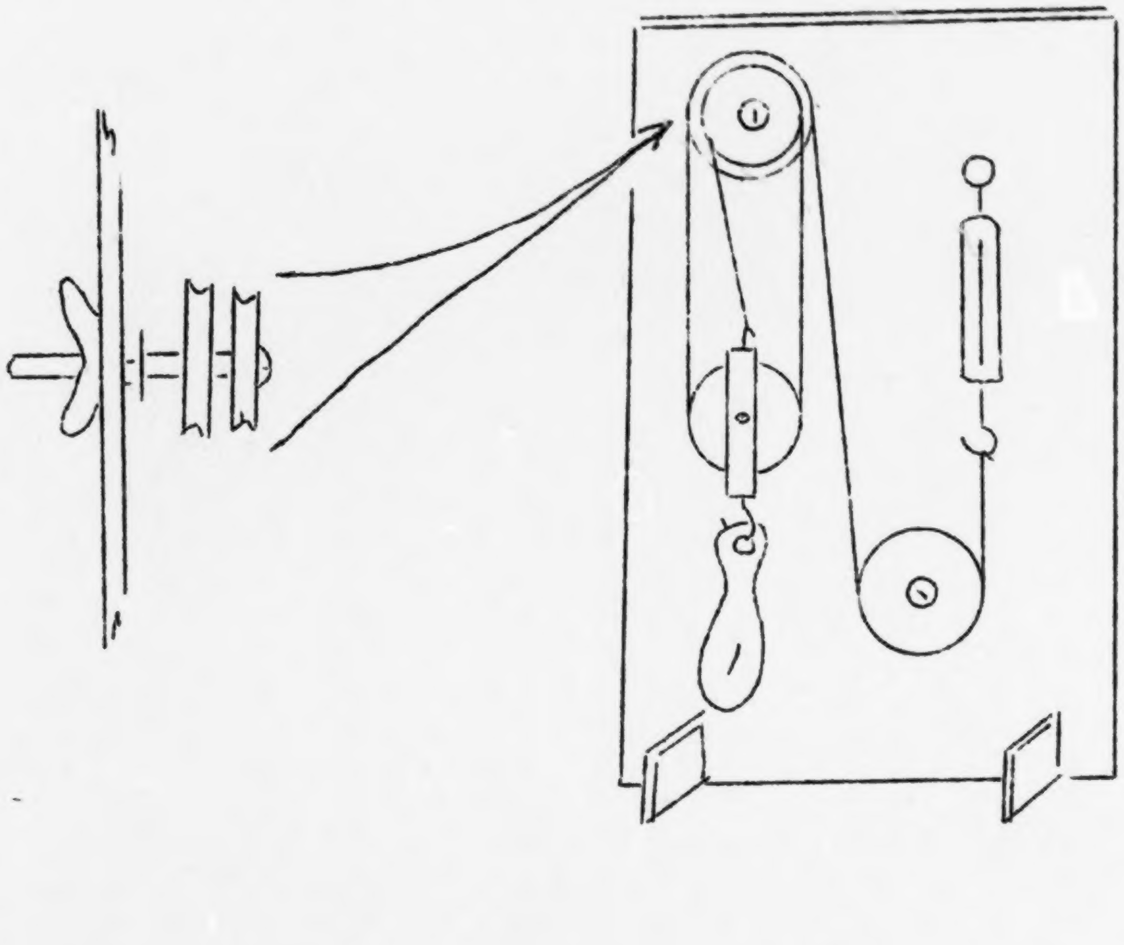
STUDENT

P - 15

COMBINATION OF PULLEYS

Materials for groups of three:

1. 1 hardboard
2. 2 slotted hardboard supports
3. 1 plastic tube
4. 1 pulley block
5. 3 pulley wheels
6. 2 bolts, 1½ inches long
7. 2 brass spacers
8. 2 nuts
9. 2 wing nuts
10. 1 lead weight
11. 1 cord, 48 inches long
12. 1 spring balance



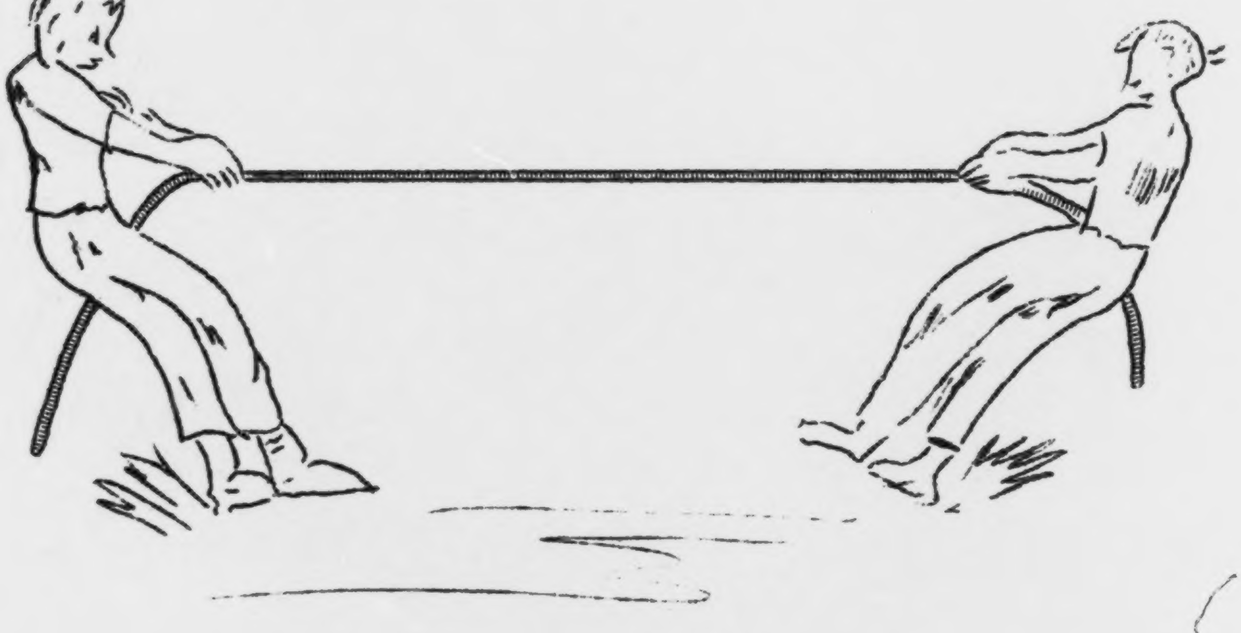
Set up your apparatus like the diagram above. Determine the mechanical advantage. If time permits, set up other combinations and determine their mechanical advantage. You should be able to determine it two different ways. Can you?

UNIT 4 FRICTION

This unit on friction should offer some real challenges to the students. The explanations for friction "acting as it does" requires some thought and imagination. Probable explanations will be shattered by the results of the next activity, and questions about apparent contradictions will arise. Do not try to get too involved in definitions and ask "how" more frequently. Questions arising will have to do with tires; wide as opposed to narrow tires, slick as opposed to tires with treads, how much air for proper friction. The class will probably arrive at the correct answer by themselves if allowed to discuss it among themselves.

The activities in this unit are:

P-16	SURFACE AREA AND FRICTION
P-17	WEIGHT AND FRICTION
P-18	TYPE OF SURFACE AND FRICTION
P-19	HEAT AND FRICTION
P-20	NEARLY FRICTIONLESS



TEACHER RESOURCE

The resistance of friction may be defined as the force that opposes the motion of one object's surface sliding over another or of one object moving through another. This may be due to the attraction of the surfaces or the irregularities of the surface, or both. The direction of the friction force is opposite that of the effort force, but it is in the same direction as the resistance force. The frictional force opposes the effort force. The force of friction is dependent on or related to the following conditions:

1. The resistance force of friction is directly proportional to the force pushing the surfaces together (weight in the case of the horizontal surface.) If it takes 1 pound of force to pull a brick, it would take two pounds of force to pull two bricks.
2. The force of friction depends on the types of surfaces involved.
3. Other things being equal, the force of friction does not depend on the amount of surface area. Whether a brick slides on the narrow side or wide side does not matter unless it digs into the surface.
4. Starting friction is greater than sliding friction. When an object sets, it settles and the surfaces come closer together increasing the attraction for each other as well as more interlocking of irregularities.
5. Heat is produced by friction.
6. Lubricants reduce friction, and so lessen the effort force required to overcome friction.
7. Substituting rolling parts for sliding parts reduces friction.

Topic 1 - The force of friction is directly proportional to the force pushing the surfaces together (weight in the case of a horizontal surface.) and with other things being equal, it does not depend on area.

TEACHER RESOURCE

Most of the students will have an awareness of friction. The teacher can capitalize on this factor in the discussions. The terms movement and motion should be used interchangeably by the teacher to introduce the term motion.

IN MANY OF THE ACTIVITIES YOU HAVE SAID THAT FRICTION SHOULD BE CONSIDERED SINCE IT CAUSED AN EXPERIMENTAL ERROR. I AGREE WITH YOU. LET'S CONSIDER FRICTION AND REALLY TRY TO FIND OUT HOW IT WORKS. WHAT IS FRICTION? (Discussion).

Use the overhead projector and write all the answers on an acetate. Approach friction as a resistance force that opposes the effort force. Each time they suggest an answer to the question, "What is friction?", ask the students if friction increases the effort force or increases the resistance force.

LET'S DEFINE FRICTION AS A FORCE THAT OPPOSES MOVEMENT. THIS IS WHAT WE HAVE REALLY BEEN SAYING, ISN'T IT? (Discussion). LET'S CONSIDER THE AREA OF AN OBJECT LIKE A PIECE OF WOOD. WHICH SIDE WOULD HAVE THE MOST FRICTION, THE WIDE SIDE OR THE NARROW SIDE? (Use a block of wood to demonstrate.) HOW COULD YOU TEST AND FIND OUT IF THE AREA MAKES ANY DIFFERENCE? (Discussion to plan P-16)

Do not tell the students the answer. Ask how freely. Also support the idea that friction opposes the effort force.

Pass out P-16.

TEACHER DIRECTION P - 16

SURFACE AREA AND FRICTION

Each group is to pull a block of wood along a flat surface by means of a spring balance connected to the block with a rubber band. The teacher should demonstrate the procedure and stress the importance of exerting the force slowly and steadily to obtain accurate results. The force required to initiate movement will be greater than the force needed to maintain a constant speed.

Students are to take turns as an observer to read the balance. Each student will record the observers' findings.

After the students complete the activity, return to a class situation to interpret the data. Using transparency P-16, discuss the findings. The important point to stress is that surface area is not important, but rather something else. Do not tell the students what the significant factors are because they will discover them in the next activity.

WHAT IS THE WEIGHT OF THE BLOCK OF WOOD? (around 5 ounces). All blocks should weigh approximately the same. Write the weight suggested by the students under both drawings of the block. LET'S CONSIDER THE BLOCK WHEN IT WAS LAYING ON ITS BROAD SIDE. WHAT WAS THE FORCE REQUIRED TO START THE BLOCK MOVING? Record the answers on the transparency. WHAT WAS THE FORCE REQUIRED TO MAINTAIN A STEADY SPEED?

NOW, LET'S CONSIDER THE BLOCK WHEN IT IS LAYING ON ITS NARROW SIDE. WHAT IS THE FORCE REQUIRED TO START THE BLOCK MOVING? Stress the relation of surface area between the two drawings on the transparency and record the finding as before. WHAT IS THE FORCE REQUIRED TO MAINTAIN A CONSTANT SPEED? Stress the relationship of the forces and the surface area. WHAT DO THESE RESULTS SHOW? The force of friction does not depend on the surface area. The starting friction is greater than sliding friction.

IF YOU INCREASED THE WEIGHT OF THE OBJECT TO BE MOVED, WOULD THE FRICTION INCREASE? Yes. (Discussion). A factor that must be considered in testing is to maintain the same surface and vary the weight. Develop the procedure of P-17 in this discussion.

STUDENT P - 16

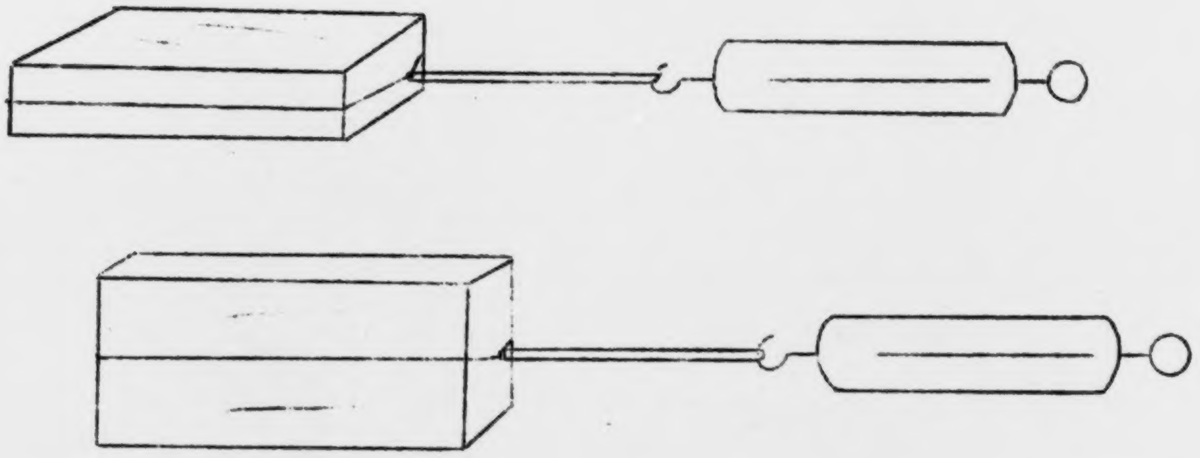
SURFACE AREA AND FRICTION

Materials for groups of three:

1. 1 rubber band
2. 1 spring balance
3. 1 piece of wood

Scientists have many ideas about friction, and their observations have been quite different from what most people expected. The activity that follows will show something that seems strange at first, but we must accept the experimental data.

Loop a rubber band around the block of wood and hook the spring balance to the rubber band as shown in the diagram below.



The block is to be moved by pulling very slowly on the spring balance until it starts to move. One student is to pull the spring balance. One student is to read the balance. One student is to record the data. Record all observations in the table on the next page. All students must complete the table.

Data on Friction

Observer Number	Force required to start the block moving	Force required to maintain a constant speed	Position of Block	Weight of Block
			WIDE	
			NARROW	
			WIDE	
			NARROW	
			WIDE	
			NARROW	

It was believed for a long time that the force of friction depended on the surface area. Do your results support this statement that the surface area is important for friction.

TEACHER DIRECTION P - 17

WEIGHT AND FRICTION

Materials for groups of three:

1. 1 rubber band 2. 1 spring balance 3. 2 wood blocks

The procedure for P-17 is identical to the procedure used in P-16. The only changes are variations in weight. Let the students pursue the activity without detailed explanations. Encourage the students to read the directions very closely.

After the completion of the activity, discuss the results using transparency P-16. Draw a second block over the single block drawn on the transparency in a different color, then record the data obtained on the transparency. Solicit results from the class following the same procedure used in P-16. Stress that weight, not surface area, as a factor in friction.

The students are to make drawings. Stress thought rather than artistic ability. The teacher should assure student understanding before the students begin drawing. Assure this understanding in small group discussion, not by class discussion. Compliment the students whenever possible. It is suggested that transparency P-16 be placed on the overhead projector to be used as reference if needed.

After the students complete the drawings, instruct them to disassemble their apparatus and return for a class discussion. If some of the students show an interest in drawing, have them prepare a transparency to demonstrate before the class.

The discussion to this point has only considered the friction involved in hard flat surfaces. It should be recalled at this point that weight is significant, but surface area is not an important factor when hard flat surfaces are used.

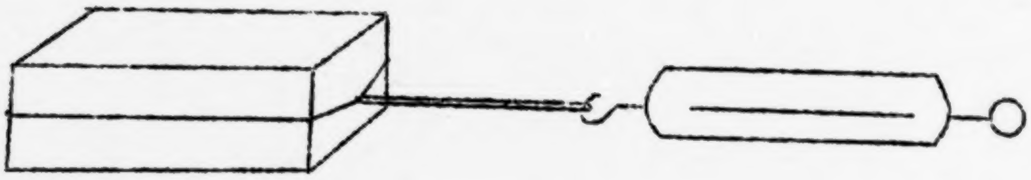
STUDENT

P - 17

WEIGHT AND FRICTION

Materials for groups of three:

1. 1 rubber band
2. 1 spring balance
3. 2 pieces of wood



How does weight effect friction on a hard flat surface? If by increasing the weight, the force of friction changes, then you could prove that weight is an important factor effecting friction.

The procedure for this activity is the same as P-16. Remember you are to work as a group. One student is to pull the spring balance. One student is to read the balance. One student is to record the data.

Complete the table below.

Data on the Effect of Increased Weight on Friction

Observer Number	Position of Block	Number of Blocks	Force required to start the block moving	Force required to maintain a constant speed
	Wide side	1		
	Wide side	2		
	Narrow side	1		
	Narrow side	2		
	Wide side	2		
	Narrow side	2		

Student
page 2

Make a drawing of the apparatus and label the **parts.** Write on the drawings the effort force observed above the spring balance. This will require four drawings. Your drawings should show a point, so first determine what you are showing, then arrange your drawings to best show your point.

Topic 2 - The force of friction depends on the type of surfaces involved.

The following activities are to invesitgate forces of friction on surfaces that are not smooth. The students will probably already know the factors involved when surfaces are not smooth or hard, but they can make a quantitative investigation. Encourage individual investigations and permit all reasonable requests to investigate suggested possibilities.

WE HAVE SHOWN THAT THE SURFACE AREA IS NOT IMPORTANT WHEN OBJECTS WITH HARD FLAT SURFACES ARE MOVED OVER OTHER HARD FLAT SURFACES. THE IMPORTANT FACTOR IS THE FORCE PUSHING THE SURFACES TOGETHER. LET'S NOW CONSIDER A CONDITION WHEN THE SURFACE IS NOT HARD OR SMOOTH. PLACE THE PALMS OF THE HANDS TOGETHER. (Demonstrate). NOW, WITHOUT EXERTING PRESSURE, START MOVING YOUR HANDS BACK AND FORTH. NOW, GRADUALLY EXERT MORE PRESSURE UNTIL YOU CANNOT MOVE YOUR HANDS AT ALL. WHAT IS THE IMPORTANT FACTOR, FORCE OR SURFACE AREA? (Both are important). Accept all answers and list the remarks on the overhead projector. Since the surface area remained the same, force again is a significant factor.

NOW, INTERLOCK YOUR FINGERS WHILE HOLDING YOUR HANDS STRAIGHT. HOLD YOUR HANDS CHIN HIGH AND TRY TO PULL THEM APART. CAN YOU PULL YOUR FINGERS APART IF YOU EXERT ALL THE PRESSURE YOU CAN? NOW, INTERLOCK YOUR FINGERS WITH YOUR NEIGHBOR'S FINGERS AND SEE WHICH ONE OF YOU CAN PREVENT THE OTHER FROM PULLING HIS HAND AWAY. Instruct the students to remain in their seats. Otherwise it may become unmanageable. SCIENTISTS SAY, FORCING TWO OBJECTS CLOSER TOGETHER CAUSES INTERLOCKING. THEREFORE, THE FRICTION INCREASES. DO YOU AGREE WITH THIS STATEMENT? (Discussion). Accept all answers. Lubricants will probably be mentioned, but a lubricant prevents objects from coming in contact with each other. The degree of attraction of the surfaces under consideration is another important factor that may arise. An example of attraction is glue; it may stick on some objects and not stick on others. LET'S INVESTIGATE SEVERAL DIFFERENT KINDS OF SUBSTANCES TO DETERMINE THE FORCE OF FRICTION AND THEN COMPARE THE RESULTS. Pass out P-18.

TEACHER DIRECTION P - 18

TYPE OF SURFACE AND FRICTION

Materials for groups of three:

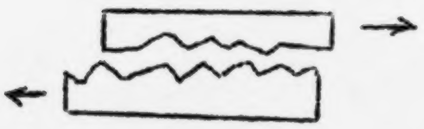
1. Spring balance
2. Blue friction board
3. Yellow friction board
4. Truck
5. Rubber band
6. Lead weight

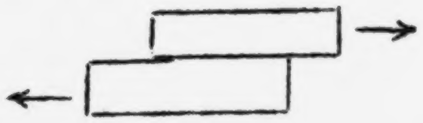
The students are to proceed on their own. They are to measure friction as it occurs between the smooth and rough sides of the friction boards. Next, they will need to go outside to some sand to test for friction occuring with sand as one surface. Instruct them to follow the directions and record all results in the tables.

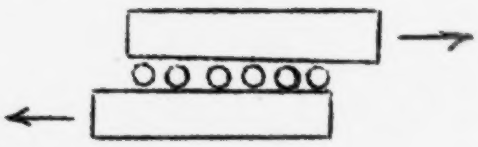
After completing the activity reassemble for a class discussion. Using transparency P-18, discuss the findings. Complete the table before answering the questions at the end of the activity. If students have questions concerning the activity, explain that the table must be completed first in order to obtain the necessary data to draw conclusions. During discussion of the table stress the point that the forces of friction in rolling friction are less than in sliding friction. Stick-slip friction is (generally) greater than other sliding friction because of the rough surface.

After completing the tables, discuss the questions using free hand drawings on an acetate to illustrate answers. Ask the students to help formulate statements to be used in writing an outline of the conclusions on this acetate along with the drawings.

Below are examples of drawings to be sketched during the discussion:







Teacher Direction
page 2

Having made the point that friction between hard surfaces does not depend on the surface area, raise questions regarding the use of large wheels or a carterpillar tread on farm tractors or on road building machinery. These tractors pull harder on loose earth than would be the case if the surface area between the wheels and the earth were less. If questions arise that can be demonstrated, allow the students to demonstrate the point in question.

After completing the questions, play the "would you believe" game.

WOULD YOU BELIEVE, A WHEEL ON AN AUTOMOBILE HAS BOTH ROLLING FRICTION AND SLIDING FRICTION? Yes. It has rolling friction in the ball bearings as well as rolling on the highway. Sliding friction is what makes the automobile move.

WOULD YOU BELIEVE THAT A SQUEAKY DOOR IS AN EXAMPLE OF SLIP-STICK FRICTION? Yes. The noise is due to an alternate sticking and slipping, sometimes called stick-slip friction. Lubrication makes the friction a continuous sliding friction by intorducing other substances that slide more easily.

WOULD YOU BELIEVE, THAT OIL ON A SQUEAKY DOOR WORKS BECAUSE THE OIL PROVIDES NEW SURFACE AND THAT THE NEW SURFACES HAVE LESS FRICTION THEN THE DRY HINGES ON THE SQUEAKY DOOR? Yes. The lubricated surfaces have less attraction. The lubrication could be an oil or graphite, both serve the same purpose.

STUDENT

P - 18

TYPE OF SURFACE AND FRICTION

Materials for groups of three:

1. Spring balance
2. Blue friction board
3. Yellow friction board
4. Truck
5. Rubber band
6. 4 ounce weight

Friction is a force that opposes the effort force. This makes friction a very important factor when trying to move objects from one place to another. Scientists classify friction in many different ways. Some of the important classifications are: sliding friction where one object is pulled over another object. rolling friction where wheels or something round is used, and stick-slip friction where an object seems to stick, then jerk forward. In this activity you will find examples of all three of these. See if you can classify them.

The procedure for this activity is the same as used in P-17. One student is to pull the object to be tested. One student is to record the data. One student is to be the observer and read the balance accurately.

Record all data in the tables on the next page.

Student
page 2

If the balance will not measure the force, write "cannot tell". Testing is to be performed on a flat table top that is smooth.

Friction on a Smooth Surface

Object	Position	Force required to maintain a constant speed	Type of Friction
Truck	Rolling		
	Side		
	Rolling + Weight		
Yellow Friction Board	Smooth side Down		
	Rough side Down		
	Rough side of Yellow board on the Rough side of Blue board		

Friction in Loose Sand

Testing is to be performed outside in the sand.

Object	Position	Force required to maintain a constant speed	Type of Friction
Truck	Rolling		
	Side		
	Rolling + Weight		
Yellow Friction Board	Smooth side Down		
	Rough side Down		
	Rough side of Yellow board on the Rough side of Blue board		

Student
page 3

Many conclusions can be drawn from the data you have recorded. By using your results answer the following questions.

1. Is friction greater in sand or on a table top? How do you know?
2. When is friction the greatest, in sliding friction, in rolling friction, or in stick-slip friction? How do you know?

When the rough surface of the yellow friction board is placed on the rough surface of the blue friction board, the resistance force of friction was very high. This high resistance force of friction is due to two things: the surface of the foam rubber and the attraction of the foam to stick together. List three examples where rubber or similar material can be used to advantage. (An example would be a rubber shoe sole replacing leather to prevent slipping).

1.

2.

3.

Sand is generally little round pebbles that are very hard. When you pull something very flat over the sand, it slides very easily. The sand in this case would be **either** sliding friction or rolling friction. Explain how it could be both sliding friction and rolling friction.

1.

Topic 3 - Heat is produced by friction. Lubricants reduce friction and therefore reduce the heat and the effort force.

The relation of friction and heat can best be explained technically by the molecular theory, but the abstraction of atoms and molecules prevents the introduction of molecular explanations. The initial approach to this topic is to provide an introduction to the unit of heat. To measure heat due to friction alone is difficult and complicated. Therefore, the activities must be limited.

Lubrication is a study of individual substances and their relation to surfaces associated with the lubricant. A substance that is a good lubricant for one surface may be a glue for another. Water is a good example. It serves as a cement in clays, whereas in a sand it provides a lubricant and allows sand to be carried with the flow of water. Secondly, the amount of the substance being applied is critical. Even in clay excessive amounts of water will serve as a lubricant as well as a glue. A lubricant basically is a substance that coats the surface of an object or objects providing a condition that will reduce friction and, therefore, reduce heat.

The first activity is a reading activity. Stress the heat relations in the discussions to serve as an avenue of approach to the unit on heat.

TEACHER DIRECTION

P - 19

HEAT AND FRICTION

The students are to read P-19. Several words need to be defined before passing out the activity: lubrication, lubricants, coated, and special applications of the inclined plane. Let the students read the activity, then read it aloud with them inviting informal discussion. The points to stress are that friction causes heat, and that lubricants reduce friction by coating the surface of the object with something that has less friction (e.g. oil, water, graphits).

Immediately after the completion of P-19, move into P-20.

P - 19

HEAT AND FRICTION

Have you ever watched a poor driver in a car try to start very fast or "spin-off" in sand? What happens? Well, a whole lot happens, but one thing that does not happen is that the automobile does not go anywhere but down--down in the sand. The unhappy driver then gets out of the car for a scientific investigation to correct his errors. If we were this unhappy driver what could we find out? Let's try to imagine the conditions and analyze the data that can be obtained.

The first and most obvious thing is that the rear wheels were spinning. The friction between the tires and the sand was not great enough to move the car forward. One explanation could be that the sand grains are round and therefore have rolling friction like the wheels. If we recall our experiments, we would remember that the more weight you have, the greater the friction. Conclusion number one would be, if the car is to get out it needs more weight over the driving wheels. But by this time the tires are deeper in the sand.

The next thing to notice would be the tires. Would the treads have enough traction? Do rough treads have more traction than smooth treads? The treads cannot be altered, but what about the surface area? Would it increase the friction if we let some air out of the tires? It would give a broader surface and the tires would not sink into the sand as fast as when it is full of air. Conclusion number two would be let some air out, but not enough to give you a flat tire.

The tires have also dug a hole into the sand. The hole is the same as an inclined plane and it takes more effort force to climb an inclined plane than to move along a level surface. So, the third conclusion is, dig some sand out from in front of the tires.

The tires were smoking when you first got out of the car and you feel one of them to see if it is hot. It is hot! Why did the tire get hot? It must be due to the friction of the tires spinning in the sand. Obviously you should wait until the tires cool. As you sit down to think you begin to think about friction and heat. It's not really unusual that the tires got hot. If you rub anything together it becomes hotter. Even by just rubbing your hands together they get hotter. If you rub a match against a piece of sandpaper it gets hot enough to burn. If you rub a piece of ice it melts faster. It seems heat is the result of friction. So, perhaps if friction is reduced, heat will be reduced. Industry uses this idea of heat and friction in all their machines.

The first real scientific knowledge was given to the world in early 1800 by an American, Benjamin Thompson. He noticed that as holes were being bored into brass to make cannons, that the metal became so hot, if a person touched it, a big blister would result. This observation lead to many investigations. Scientists began developing lubricants such as oil, grease, graphite, plastics and many others. They discovered that smooth surfaces reduce friction and that hard "ball shaped" objects, called ball bearings, have the least amount of friction. So the ball bearing was developed and oil was added as a lubricant. Lubricated ball bearings were a most important invention. It is said the wheels of industry turn on lubricated ball bearings.

Scientists continued to investigate lubrication and the findings are not unusual. The lubrication does one thing, it coast the surface of the object and therefore gives another surface that has less friction. Lubricants do not have to be a liquid, but can be a plastic or even a gas. Just the addition of a new surface that has less friction is a lubricant.

Millions of dollars have been spent on lubrication. Heat, however, is not the only reason lubricants are used. Lubricants also prevent objects from wearing out so fast. What actually takes place is that the surface of the object is coated and doesn't touch anything but the lubricant. Friction is needed sometimes like on the brakes of a car. It would be a sad day if someone oiled the brakes on a car. What happens to your brakes when they get wet? It would be another sad day if someone poured oil on the highway. What do you think would happen if someone put grease all over a railroad track?

It seems we have forgotten about the stuck car, so let's dig out in front of the tires and start off very slowly. It may work, and the car can travel to wherever the driver wishes to go.

Just one question seems unanswered. Why do boys lubricate their hair? Some even use that "greasy kid stuff".

TEACHER DIRECTION P - 20

NEARLY FRICTIONLESS

Materials for groups of three:

1. Small block of dry ice. 2. Tongs

Each group will need a small piece of dry ice (solid carbon dioxide). If you receive a large piece of dry ice, use a hammer to break it into small pieces. The shape of the ice is not important. The ice has the characteristic of sublimation (changes directly from a solid to a gas). The ice floats on its evaporated gas, when it is placed on a smooth hard surface.

Pass out P-20

THE OBJECT YOU HAVE IS FROZEN CARBON DIOXIDE, CALLED DRY ICE. IN SOME CASES IT IS NEARLY FRICTIONLESS DUE TO THE GAS IT IS GIVING OFF. WHAT DOES THE GAS DO? (Serve as a lubricant). TRY IT AND SEE, THEN ANSWER THE QUESTIONS ON THE ACTIVITY SHEET. Let the students proceed on their own. Caution the students that they can get 'burned' with dry ice.

STUDENT P - 20

NEARLY FRICTIONLESS

Materials for groups of three:

1. Dry ice (frozen carbon dioxide) 2. Tongs

Everything that moves has some opposing friction. Just movement in the air provides an opposing force against movement, or friction. In this experiment you are to use dry ice. This substance is a solid that doesn't melt, it just evaporates. The gas that is given off provides a lubricant, or in other words, the block of ice produces a gas that floats the solid above the table.

NOTE: DRY ICE WILL 'BURN'. HANDLE THE ICE WITH TONGS ONLY.

Your instructor will show you where to test the ice for friction. Follow his directions for safety.

1. Place the ice in the location assigned. Then barely touch the block of ice with your tongs to see if it will move easily.
2. Blow on the ice and see if you can move it by blowing it.

Answer the following questions: (Use the back of the sheet if needed)

1. Is the block of dry ice nearly frictionless?____________ How do you know?

2. What is the lubricant?__________________________ How can you tell?

3. Would a block of regular ice work the same way?_______ Why or why not?

4. If ice melts to water, would the water act as a lubricant or as a glue?______ _________________ How can you test it?

5. Why is it so easy to skate on ice?

6. What happens when you touch an ice tray from the freezer with wet hands.

UNIT 5 HEAT

This unit on heat is designed to give the students some experiences in measurement, effects, and movement of heat and heat energy. The final activity will lead into the next unit which will be built around water, starting with buoyancy.

The activities in this unit are:

P-21	HEAT ENERGY
P-22	HERO'S ENGINE
P-23	TEMPERATURE
P-24	GRAPHING
P-25	EXPANSION OF METALS
P-26	HEAT: WEIGHT AND VOLUME
P-27	CONDUCTION - CONVECTION - RADIATION
P-28	HEAT OF FUSION - HEAT OF VAPORIZATION

TEACHER RESOURCE

Heat is a term relating to a form of energy. The direction of flow of heat energy is determined by differences in the temperature. It should be noted that temperature is not a measure of heat, but a measure of "hotness" and "coldness". The heat will flow from the hot area to the cold area. The temperature is a qualitative measurement indicating the direction of the flow of heat. It is commonly measured in degrees on the Fahrenheit and Centigrade Scales. Technically, temperature can be defined as the state of a body which determines the transfer of heat to or from other bodies. Heat energy always flows from a body AT A HIGHER TEMPERAATURE TO A BODY AT A LOWER TEMPERATURE. Whenever heat energy flows from a hotter body into a cooler body, the hotter body loses energy and the cooler body gains energy. The heat transfer is therefore an energy loss or gain in the internal energies of the bodies. Heat refers to the quantity of energy present while temperature refers to the degree of "hotness" or "coldness". Heat energy is measured by B.T.U.'s (British Thermal Units) or in calories. One B.T.U. is the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit One calorie is the amount of heat required to raise the temperature of one gram of water one degree Centigrade. A Kilocalorie (large calorie, food calorie, written with a capital 'C') is the amount of heat required to raise the temperature of one kilogram (1000 grams) of water one degree Centigrade. The relationship of heat and temperature must be made clear to prevent confusion.[1]

Heat is a form of energy. Temperature is a qualitive measurement of this energy. The following statements can be made concerning heat and temperature:

1. Heat is energy and therefore can perform work.
2. Temperature can be measured by the various scales using the principle of expansion and contraction of a confined medium.

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[1] A good reference is Dull, Metcalfe, and Williams, Modern Physics, New York: Holt, Rinehart, and Winston, 1960, pp 217-229

3. Heat will move from the higher temperature to the lower temperature.
4. Evaporation is a process of heat exchange and therefore can produce cooling due to the release of heat energy from the internal system undergoing evaporation.
5. The rate of cooling is not a straight line relationship but a curved line. A graph will readily prove this relationship when temperature is plotted in relation to time.
6. Differing materials exhibit differing insulation qualities.
7. The kindling temperature is the temperature at which a substance will take fire and continue to burn. This temperature is critical. Below this temperature no flame will occur. Above this temperature or at this temperature flames might occur.
8. The rate of chemical reactions are influenced by temperature.

The activities in this unit are to develop an appreciation of the energy relationship of heat. Heat is a vital factor in everyday life. It is one of the most important factors in our physical and biological environment. The orientation of this entire unit will reflect these relationships.

Topic 1 - Heat is energy and can perform work.

The introduction of the heat relations should follow smoothly and without a recognizable break following friction. The last two activities (P-19, P-20) stressed the relationship of heat, friction, and the use of a gas to reduce friction. The gas, however, was from a very cold piece of dry ice. The heat relation is the important factor that will provide the basis of approach.

The steam engine may be used in this section at any opportune time, if interest is high enough. You may wish to probe deeper into the actions of the engine, but little reference will be made to the steam engine in this material. You may wish to prepare a transparency.

INDUSTRY HAS SPENT MILLIONS OF DOLLARS TO REDUCE FRICTION. IT HAS ALSO SPENT MILLIONS OF DOLLARS TO FIND BETTER WAYS TO USE THE ENERGY OF HEAT. LET'S SEE HOW MANY APPLICATIONS OF HEAT ENERGY WE CAN LIST. Write all suggestions on an acetate.

Interject the term energy at every opportunity and compliment the use of it, but do not require its use. If temperature is used in student discussion, explain it as an indication of hotness and coldness, but do not discuss the relationship of temperature and heat at this time. Along with every suggestion stress movement of the heat energy from one location to another. An example would be, if someone names a stove, remark the heat energy travels into the food being cooked, or ask the students what direction the heat is moving.

WE COULD GO ON AND ON AND ON WITH THIS LIST BECAUSE WE USE HEAT SO MUCH. LET'S TAKE A LOOK AT WHAT WE ALREADY KNOW. THE FIRST THING WE SEE IS THAT HEAT MOVES FROM ONE PLACE TO ANOTHER. REGARDLESS OF WHAT CAUSES THE HEAT, IT MOVES, SO LET'S LOOK AT SOMETHING THAT REALLY HAS A LONG HISTORY OF IMPORTANCE TO SCIENCE. (Pick up a drill and bit). WHAT IS THIS? Discussion if needed, but all the students should be very familiar with the drill. DO YOU BELIEVE THIS WILL PRODUCE HEAT? Accept all answers but do not explain what you are doing to do. Ask one student to volunteer to assist you. Then drill a small hole in a block of hard wood. Ask the student to touch the bit carefully so he can feel the heat transfer. WHAT HAPPENED? Discussion. WHERE DID THE HEAT COME FROM? (Friction). WHERE DID THE HEAT ENERGY TRAVEL TO? (The air and the boy's hand). IT SEEMS THAT WE CAN REMOVE THE HEAT. CAN YOU THINK OF ANY WAY WE COULD KEEP THE BIT COLD? The answer you are seeking is to obtain something that will absorb the heat. If you do not get the answer you want, then suggest that water might be used to remove the heat. Ask for a volunteer to fill a beaker with water and pour it on the bit slowly to prevent splashing. After drilling, immediately tell the student pouring the water to touch the bit. It will be cooler. WHAT HAPPENED TO THE HEAT ENERGY? (Absorbed by the water). HOW DOES INDUSTRY USE THE SAME PRINCIPLE? (use oil). This same demonstration can be extended to movement of heat in the metal being drilled. The main point to develop is that heat travels from the hotter area to the colder area. WE MENTIONED EARLIER THAT THIS EXPERIMENT HAD HISTORICAL IMPORTANCE, SO LET'S READ ABOUT ONE OF THE SCIENTIFIC GIANTS OF HEAT EXPERIMENTATION.

Pass out P-21

TEACHER DIRECTION P - 21

HEAT ENERGY

The reading activity is to reinforce the concept that heat is energy. After the students complete the reading, read the activity aloud with them while raising questions. The experiment by Count Rumford will need more explanation. The discussion of the experiment can develop the importance of comparison and that this is a valid means of experimentation recognized by scientists. Also make the point that science is continually changing due to questioning and experimentation.

Several words will need to be defined before the students begin reading. They are internal combusion engine, communicated (meaning transferred or moved), associated with, influential, espionage, deported, and distinct.

The reading may stimulate interest to the point that outside reading and reports can be introduced. In this connection, students might read about Robert Fulton, a colorful scientist, and others such as James P. Joule, James Watt, Thomas Newcomen, and Dr. Rudolph Diesel.

The work that heat can perform is the most applicable community-related aspect. The following activities will investigate several of the applications of heat energy.

It might be interesting to discuss several current applications of heat energy to perform mechanical work and the efficiency of these and other machines. Some would be:

Atomic Reactor	100% efficient
Electric Motor	95% efficient
Locomotive	25% efficient

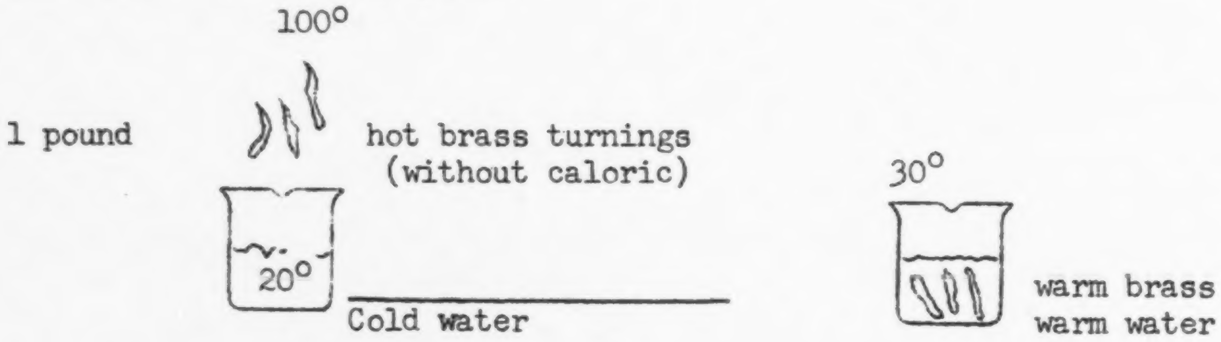
STUDENT P - 21

HEAT ENERGY

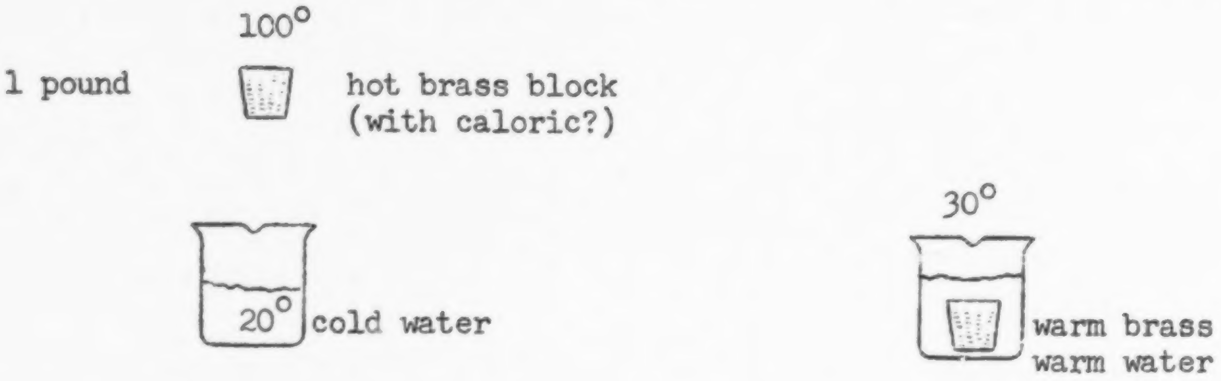
Benjamin Thompson was born on a small farm in Massachusetts in 1753. He was a bright young man that moved from his farming community into the city where he became associated with influential people. When the Revolutionary War broke out in 1775 Mr. Thompson became a British spy, was caught by the Americans, and deported to England. The English government awarded him an important governmental post as head of the Bavarian War Department due to his espionage activities and his keen interest in science. The British government also gave Benjamin Thompson a noble title, Count Rumford. The Count was most interested in heat and read widely on the subject. Through experimentation he developed new theories and several inventions such as the drip coffee pot and the pressure cooker which are still used today.

Perhaps his greatest contribution was his theory related to heat. One day in Munich, Germany he was supervising the building of cannons. The cannons were made of long brass tubes that were bored out by long drill bits turned by horses, for then electrical power was not known. As the bit turned in the brass rod, it became hot enough to burn the men if accidentally touched. Count Rumford suspected the heat was due to friction, but the scientists during this time believed heat was a liquid called "caloric" and that the turning made the caloric run out. Therefore the heat was hot due to the caloric liquid. This seems foolish to us now, but it was a real problem in Count Rumford's time. You know they even believed when you built a fire you were being sprayed with this caloric liquid and this was what warmed you. The Count, a distinquished scientist, decided to test this theory. His experiment was very easy, but very important. He believed two things. First, if a liquid carried the heat, then it must have weight. Secondly, if caloric was once removed from the brass, it could not be heated up again because caloric was no longer present. Count Rumford wrote, "It appears to me extremely difficult, if not impossible, to form any distinct idea of anything capable of being excited or communicated, in the manner heat was communicated in these experiments, except it be motion."[1] He based this statement on his experiment in which he used brass turnings that had been bored from the cannon, cooled, then reheated over a fire, and then placed in water to be cooled again. He took the temperature of the water both before and after cooling the turnings.

He compared the heat transfer in the turnings to the heat transfer which occurred in a solid piece of brass that weighed the same as the turnings. Lets' look closer at the equipment.


100°
1 pound
hot brass turnings
(without caloric)
20°
Cold water
30°
warm brass
warm water

The brass block weighed the same as the turnings. Both were heated to the same temperature. The change in temperature of the water was the same in both cases. Therefore, the same amount of heat was transferred from the turnings as was transferred from the block. The caloric theory was proven wrong.


100°
1 pound
hot brass block
(with caloric?)
20°
cold water
30°
warm brass
warm water

---

[1] Conant, James, Harvard Case Histories. Harvard University Press: Cambridge, Mass. 1957, p. 188.

The mechanical energy of the drill was the source of the heat energy. Heat energy must be energy of motion.

Scientists came to recognize that Count Rumford was correct and as a result, science took a giant step. Soon after Count Rumford proved that heat is energy that can be transferred, the steam engine was developed and heat energy was put to work. Just think, the steam engine became the power source of the steam boat. Some made tractors for farmers using steam engines. Others used the steam engine to run pumps, elevators, and to run nearly every conceivable device for which we now use electric motors and internal combustion engines. Even in atomic reactors, it is the heat energy that we use to drive our machines.

TEACHER DIRECTION P - 22

HERO'S ENGINE

Materials for groups of three:

1. Metal can (Hero's engine)
2. Can holder
3. Cord, 24 inches long (nylon)
4. Alcohol burner
5. Ring stand

Ask students to bring small cans to make their own Hero's engine. The can must be square or rectangular (not round). The holes in the cans must be very small. Use a non-twisted thread such as nylon. Remove any combustible material from the cans by washing with soapy water.

MANY CENTURIES AGO A GREEK IN ALEXANDRIA, EGYPT, MADE A SIMPLE STEAM ENGINE USING HEAT ENERGY. LET'S TAKE A LOOK AT ONE. THIS SHOULD SHOW HEAT WILL DO WORK. Pass out P-22.

Instruct the students to follow your directions. Using transparency P-22, insturct the students to assemble their apparatus, but do not start it until instructed to do so. After the apparatus is assembled, instruct them to follow directions as written and proceed with caution due to the fire.

After completing the activity, discuss the findings in a class discussion. The principle of action and reaction will be obvious. It may be of interest to the students that the same principle of the Hero's engine is used in turning space ships when in flight in outer space.

STUDENT

P - 22

HERO'S ENGINE

Materials for groups of three:

1. Metal can
2. Can holder
3. Nylon string, 24 inches
4. Alcohol burner
5. Ring stand

Many centuries ago a Greek named Hero developed a steam engine. It is a good example of putting heat energy to work. You can make one if you wish. Some students have tournaments with Hero's engines to see who can make theirs go the fastest. Others have attached pulleys to see whose engine develops the most power. Your instructor may let you select a champion in Hero engine construction if enough would like to compete.

The Hero engine works on two principles: First, heat energy, and secondly, for every action there is a reaction. In this case water is changed to steam using heat energy and the action is the steam pushing out the little holes.

The instructor will give you directions in assembling the engine. Follow directions closely and do not light the burners until told to do so.

The alcohol burner is to serve as a source of heat energy. The water in the can will absorb the heat. The water turns to steam as it absorbs heat energy from the flame.

Put about one inch of water in the bottom of the can and screw the cap on the can tight so steam will not leak through the cap. It will take a few minutes after the burner is lit for the water to absorb enough heat to cause turning.

Count the number of turns the can makes per minute each two minutes. One student is to watch the clock and make sure the counting starts at the right time and stops at the right time. One student is to count the turns, or revolutions. The third student is to record the data.

Student
page 2

Start counting the revolutions per minute three minutes after the alcohol burner has been lit and placed under the Hero's engine. Make sure the tin can is not turning before placing the burner under the can. The can should be suspended by a thin monofilament cord such as nylon fishing line.

TIME	WAIT	4	6	8	10	12	14	16	18	20
REVOLUTIONS per minute	3 MINUTES									

Make a drawing of the Hero's engine in the space below. With arrows show the direction of the turning and the direction the steam is blowing out.

How can you make the engine turn faster? List several ways and give your reasons for listing them. If you can't think of several ways, look in some books in your room. The quickest way is to look in the index in the back of a book. Look for Hero's engine or Hero.

Topic 2 - Temperature can be measured by the Fahrenheit and Centigrade scales. It is a measure of the hotness of an object.

The term "temperature" should be an everyday word with the students, but only a few will understand the relation of temperature to heat. The following activities are to show that heat is energy and temperature is only the degree of hotness and coldness. In discussion, use the term energy after heat whenever possible, and degree of hotness when referring to temperature. The relation of heat to temperature is an abstraction and must be developed. Communication skills will develop via teacher led discussions as the students use definitive terms correctly. Use thermometers that have dual centigrade and Fahrenheit scales. The students are to read the scales directly from the thermometer. It will be unwise to attempt calculations determining conversions unless the students wish to calculate conversions. The formulas are:

$$F = \frac{9}{5}(C) + 32 \qquad C = \frac{5}{9}\ (F - 32) \qquad 1^\circ\ C = 1.8^\circ\ F$$

Graphing will be introduced in P-24. Graphing can basically show trends for many times experimental errors will make some points invalid. These points should be discarded but some attempt should be made to explain the errors involved. Approach graphing as a mathematical tool used to make predictions. Do not expect student success immediately. The students' previous unsuccessful experiences with graphing may create some apprehension. Illustrate on transparency P-24 how simple data may be graphed.

TEACHER DIRECTION

P - 23

TEMPERATURE

Materials for groups of three:

1. 250 ml beaker
2. Thermometer
3. Ice
4. Alcohol burner
5. Ringstand

Do not be surprised if the students do not know which end of the thermometer to submerge for reading. Some students will have trouble locating the mercury column. The following activities will develop confidence by letting the students discover how to read the scales.

Caution students that thermometers are not to be used as an oral thermometer. The thermometer is not to be allowed to rest on the bottom of the beaker as the beaker is being heated (the thermometer will break).

WE HAVE STUDIED ABOUT HEAT ENERGY AND SEVERAL OF YOU HAVE MENTIONED TEMPERATURE. SO LET'S DO SOME WORK WITH TEMPERATURE. (Pass out the termometer). WHAT DO YOU CALL THAT THING I JUST GAVE YOU? Thermometer. WHAT DO YOU DO WITH A THERMOMETER? Accept all answers, but challenge any statement regarding heat by answering that heat is energy and must go from a hot area (high energy source) to a cold area (low energy source), so what must temperature indicate? It indicates the direction of flow of the heat and the relative energy states of the object. At the most opportune time continue with, LET'S DEFINE TEMPERATURE AS THE DEGREE OF "HOTNESS" OR "COLDNESS". NOW, LOOKING AT YOUR THERMOMETER, HOW HOT IS IT IN THIS ROOM. Place transparency P-23 of the thermometer on the overhead projector. Record all suggestions of temperature on the appropriate scale.

Accept all answers with some comment such as "ok" or "I don't believe it". Promote discussion among the groups. Ask one group to check another group's reading. It will be good if you can ask a group that is giving Fahrenheit readings to check another group that is reading the centigrade scale.

EVERYONE LOOK AT THE TOP OF THE THERMOMETER. FIND THE LETTERS "C" AND "F". Pause.

WHAT DOES THE "C" STAND FOR? Centigrade. WHAT DOES THE "F" STAND FOR? Fahrenheit. THESE SCALES ARE TWO WAYS TO READ TEMPERATURE. IT JUST TELLS YOU HOW HOT OR HOW COLD THINGS ARE. LET'S SEE WHO IS THE HOTTER, BOYS OR GIRLS. GRIP THE THERMOMETER IN YOUR HAND. THREE MINUTES FROM NOW WE WILL TAKE A READING. Decide what scale to read during these three minutes. WHICH SCALE DO YOU WANT TO READ? CENTIGRADE OR FAHRENHEIT? (Discussion). After time is up, average all the girls readings and all the boys readings. Repeat the activity placing the thermometer in the bend of the elbow using a different scale. Stress the use of Fahrenheit since this is the most commonly used in the community. Make sure the students are proficient in reading both Centigrade and Fahrenheit scales.

AT WHAT TEMPERATURE DOES WATER FREEZE TO BECOME ICE? 32° F or 0° C. Accept all answers, but do not tell the students the correct answer. LET'S FIND OUT.
Pass out P-23.

The students are to determine the freezing point and boiling point of water. They are also to take a reading every 2 minutes in order to graph the results. They are to read the thermometer with the bulb of the thermometer in the water.

The students may use the thermometer for a stirring rod, but they are not to leave the thermometer in the water without moving it. Caution the students to take readings accurately at the prescribed intervals.

The beakers are to be one-third full of ice water with only a small quantity of crushed ice to reduce the temperature of the water to the freezing point. When the temperature cools to 32° F, have the students remove all but one tiny piece of ice. Timing and heating should start when the temperature is approximately 32° F and a small quantity of ice remains. Due to the difficulties in doing heat experiments and errors in the thermometer, a temperature of 32° F is sometimes impossible to obtain; accept any temperature below 34° F.

Teacher Direction
page 3

After completion, go over the data using transparency P-23 of the temperature scale by writing in the times of each reading between the Centigrade and Fahrenheit readings. Students are to follow using page 2 of P-23.

The results are to be used in making the graph P-24. If the students data does not yield a reasonably good graph, have them obtain data from another group.

STUDENT

P - 23

TEMPERATURE

Materials for groups of three:

1. Thermometer
2. 250 ml beaker
3. Small quantity of ice
4. Alcohol burner
5. Ring stand

Temperature is a measure of "hotness" of an object. We know that if we put ice in water, the temperature should drop to 32° Fahrenheit and remain at this temperature as long as ice is present. This activity will show that the melting ice will cause the temperature of water to drop to 32° F, the freezing point of water. Then by heating the water over an alcohol burner, we can determine the boiling point of water.

The procedure must be followed carefully. Add ice water to the beaker until it is one-third full. Add a small piece of ice and stir it slowly and carefully with the thermometer until the temperature reaches approximately 32° F. While waiting for the temperature to drop, adjust the ring stand to the proper height and light the burner. When the temperature reaches 32° F, record the exact time, minute and second. Remove all but a tiny piece of ice and place the beaker on the ring stand over the alcohol burner.

While the water is heating, stir slowly with the thermometer. Do not ever let the thermometer rest on the bottom of the beaker; this may damage the thermometer.

To complete the data table you must take a reading every 2 minutes and record the temperature in the proper space on the chart. Do be accurate, for these results will be used in the next activity.

Complete the table below. Be sure the temperature is recorded in the proper space under the correct time interval.

Student
page 2

FREEZING TO BOILING

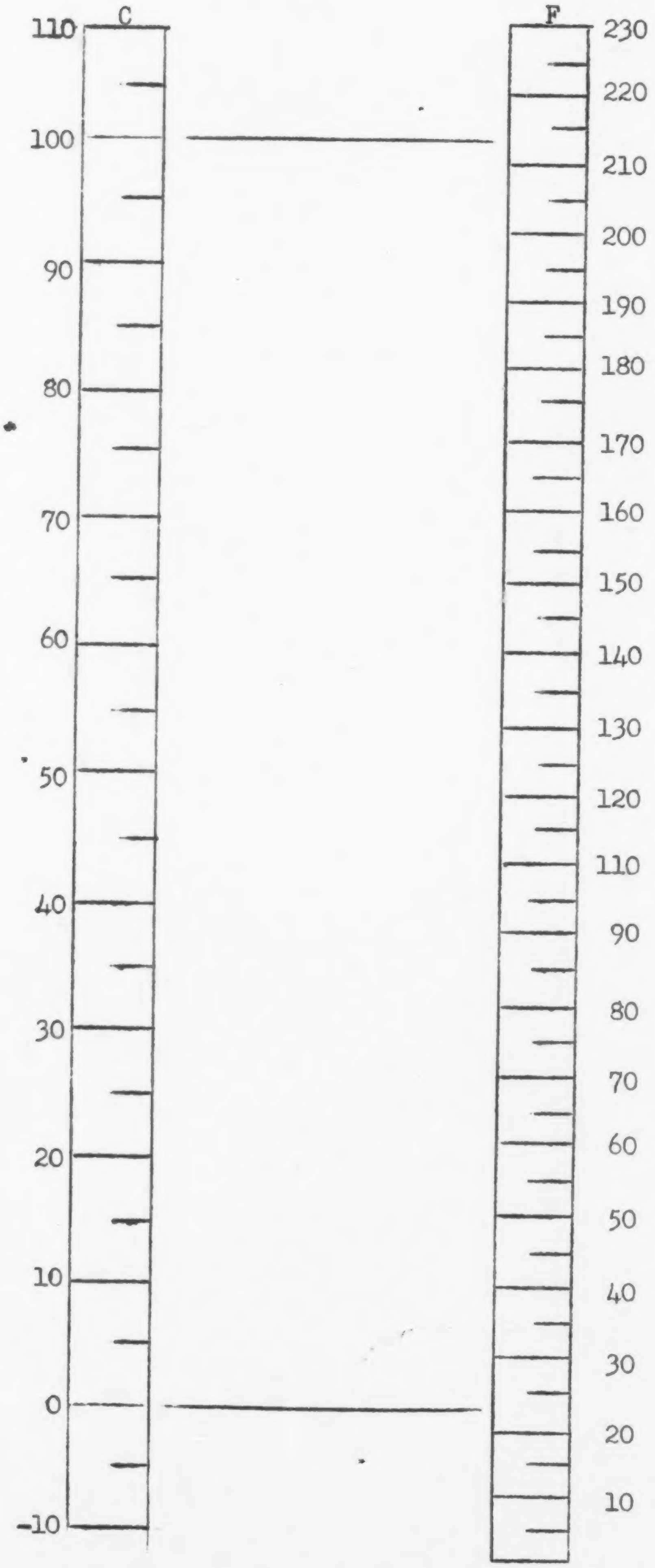
Intervals in minutes

TIME	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
TEMPERATURE Fahrenheit															

Starting time: Minutes_______________ Seconds____________________

What is the boiling point of water?__________________ How do you know?

Student
page 3


C
F
110
100
90
80
70
60
50
40
30
20
10
0
-10
230
220
210
200
190
180
170
160
150
140
130
120
110
90
80
70
60
50
40
30
20
10

TEACHER DIRECTION P - 24

GRAPHING

This activity provides experience in making a graph, a useful tool for analyzing data. The graph will be a broken line graph and not a curved line. Starting at 32°F, the line should run horizontal for a short distance until the ice has melted. This line remains horizontal due to the absorption of heat energy in melting the ice. The line will then rise at about a 45° angle until the water starts to boil. The line again becomes horizontal and will remain so until all the water has boiled away. The temperature remains constant due to the absorption of heat energy as liquid water changes to water vapor (steam).

The terms HEAT OF VAPORIZATION and HEAT OF FUSION should be introduced and used in the discussion and explanation, but should not be imposed on the students for memory.

Use transparency P-24 for recording the students' data for discussion. Using several student's data for showing the same results will be good. The difference in location of graph will reflect the differences in the quantity of heat produced by the different burners. The steeper in slope, the faster the water was heated, or the more heat energy the burner was producing. Also some groups may use more water than others. The smaller the quantity of water used, the steeper the slope will be.

STUDENT

P - 24

GRAPHING

The purpose of this activity is to convert the data you obtained from the previous activity into a more useful form. Graphing your results will make the data easier to interpret and much easier to read. It will enable you to guess what might happen if you continued the experiment over a longer period of time.

A graph consists of two parts, the horizontal and vertical axis. The horizontal axis runs across the page and the vertical axis runs up and down the page. On the graph you will be using, time (in minutes) will run from the left side of the page to the right side along the horizontal axis. The temperature starts near the bottom of the page and increases as you go up the page along the vertical axis.

To locate a point on the graph, move horizontally across the page from the temperature recorded in your data. Next, move vertically from the proper time interval straight up the page. Where the two imaginary lines cross, make a point. Follow this same procedure for all of your data. After finding all your points, connect them with the best smooth line that goes closest to the greatest number of points. In this case the line is a straight line.

The graph for your group will not be the same as the graph your neighboring group will make. It should, however, have the same general shape. Can you figure out why? Can you tell more from the graph you made than you can from the data recorded in your table?

Student
page 2

Topic 3 - The Kinetic Molecular Theory of heat is a model of matter as consisting of moving molecules.

Models are useful in explaining what one observes. Models are in reality a visual picture of an idea. One visualizes how something works. An example is the model of the solar system which we use in accounting for the motions of the planets, day and night, seasons and the like. Likewise, molecular theory is a model of the nature of matter. It enables us to account for many phenomena such as expansion of things when heated, the pressure of a gas, the energy involved in change of state, the movement of heat energy, the spread of odors, et at. We shall use it in extending our knowledge of heat energy.

TEACHER RESOURCE

The assumptions on which Kinetic Molecular Theory is based are as follows:

1. Matter in all its forms (gases, liquids, solids) is composed of extremely small particles called molecules. Molecules in turn are composed of atoms.
2. Molecules are in constant motion with speeds which increase with an increase in temperature.
3. Molecules are separated by spaces as though they were vibrating or bouncing spheres. In solids, the spaces are small and motion is limited; motion consists largely of vibrations with the molecules keeping approximately the same relative position. In liquids the molecules move more freely shifting their relative positions (as when a liquid is poured), but clinging together; and the molecules tend to fly away from each other. In gases the molecules are essentially free from all of its neighbors and they act as a completely chaotic mess. The molecules move in all directions with all possible speeds. When molecules collide they bounce from each other as if they were completely elastic with no apparent loss of energy.
4. The molecules in solids and liquids attract each other with forces that act like gravitational forces. It is assumed that there are no forces acting between molecules in a ideal gas.
5. When matter is compressed, the size of the molecules remains the same, but the spaces between the molecules are decreased. Thus a gas, with wide spaces

between the molecules, is compressible.

6. The pressure of gases is produced by the moving molecules colliding with the walls of the container. When the motion and the number of collisions of the molecules are increased the pressure becomes greater.

Theories are useful to the extent that they enable us to build mental models to more effectively investigate and arrive at more meaningful conclusions. In building the model of molecular structure, start with the assumption that all matter consists of molecules which are in motion due to their energy, heat energy. The model of each of the three states of matter can be generalized as follows:

1. Solid

   The heat energy in solids is low and thus the motion of the molecules is slow and restricted to one location in the material. The molecules are close together with little space between them. This closeness of the molecules is why solids are heavy; more molecules occupy a unit volume.

2. Liquids

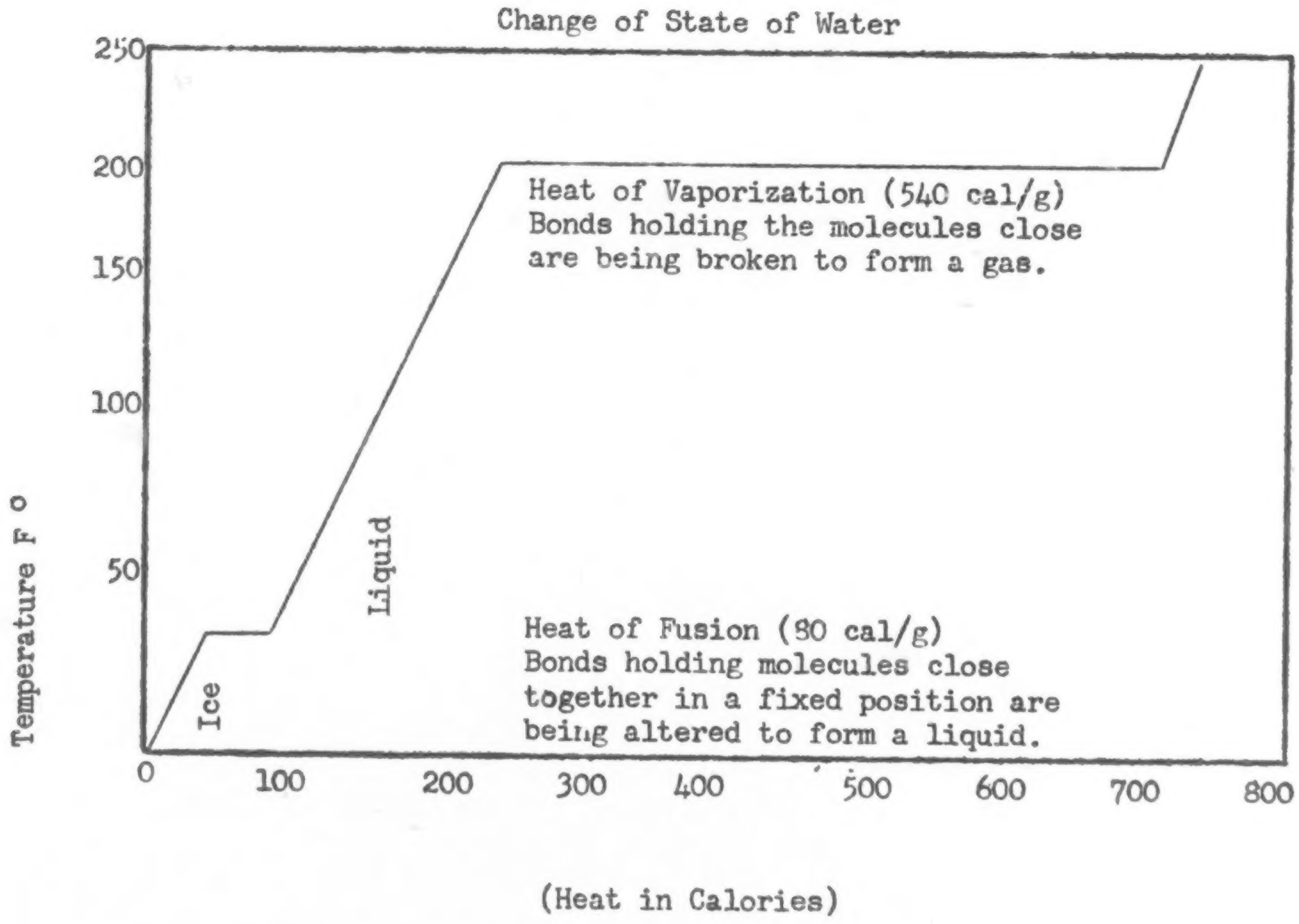
   The heat energy in liquids is higher than in solids, and thus the motion of the molecules is faster than in solids and is not confined to one location. The molecules are not as close together with a little more space between them than in solids. Since there is more space between molecules in liquids than in solids, most liquids are lighter than solids. (Ice is an exception because of its unique crystalline structure.)

3. Gases

   The heat energy in gases is higher and thus the motion of the molecules is faster and nearly completely independent of the other molecules. The molecules are far apart with a lot of space between them. This vast free space explains why gases are so much lighter than solids and liquids.

Teacher Resource
page 3

The above statements have identified solids, liquids, and gases in terms of heat energy differences. The process of changing solids to liquids and liquids to gases requires a specific quantity of heat. The heat required to change a liquid to a solid (e.g. water at 32° to ice) without changing the temperature is called the HEAT OF FUSION. The heat required to change a liquid to a gas (e.g. water at 212° to steam) without changing the temperature is called the HEAT OF VAPORIZATION. The relationship of these quantities of heat, temperature change, and the accompanying change of state are shown on the graph below.



TEACHER DIRECTION

P - 25

EXPANSION OF METALS

Materials for groups of three:

1. Glass jar and metal lid
2. Boiling water
3. Ball and ring expansion apparatus
4. Alcohol burner

This activity will make use of 'if - then' predictions to move the students toward abstract reasoning. Do not tell the students the expected outcome. The students are to compare data of two experiments showing the same principle. Read the prediction to the class and discuss it as long as there are questions.

Pass out P-25

IF MOLECULES ARE SEPARATED BY SPACES AS THOUGH THEY WERE BOUNCING BALLS, AND IF THE MOTION OF THE MOLECULES SPEED UP WHEN HEATED, THEN THE SUBSTANCE SHOULD GET BIGGER WHEN HEATED.

The following two experiments should demonstrate the effect of heat on substances. Circulate among the students asking leading questions and supplying information when needed.

1. To find out if heat makes solids expand, show how it effects a metal jar lid on a glass jar. Screw on the lid tightly. Then quickly heat the lid in hot water (boiling) and immediately try to unscrew it using a towel. Use care not to heat the glass jar.
2. To find out if heat makes solids expand, use a ball and ring. Alternately heat the ball then the ring to see if the ball will pass through the ring each time. This experiment works very well. Caution the students not to burn themselves.

STUDENT

P - 25

EXPANSION OF METALS

Materials for groups of three:

1. Glass jar and metal lid
2. Boiling water
3. Ball and ring
4. Alcohol burner

In this activity you are to consider two conditions, draw conclusions, and support or reject a prediction. The prediction may or may not be right.

PREDICTION

_If_ molecules are separated by spaces as though they were bouncing balls, and _if_ the motion of the molecules speed up when heated, _then_ the substance should get bigger when heated. To find out if things expand when heated, try the two experiments below.

Screw the jar lid on the jar tightly. Submerge only the metal rim of the lid in boiling water, then immediately pull it out and try to unscrew the lid. Remember you screwed the lid on very tight.

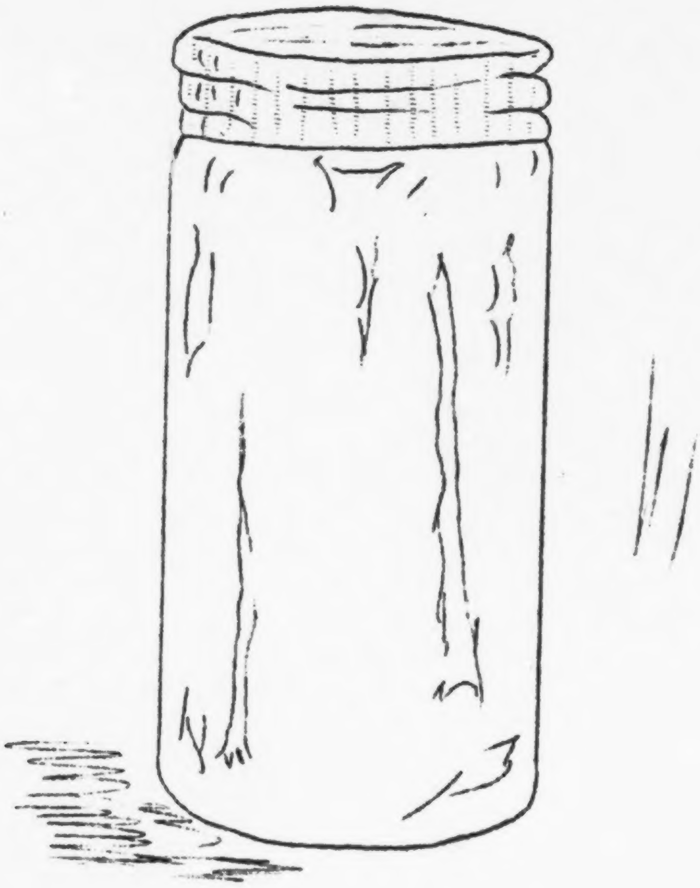
1. Was the lid easy to unscrew? ____________________
2. Did the metal expand or contract?____________________
3. How does the metal expand?______________________

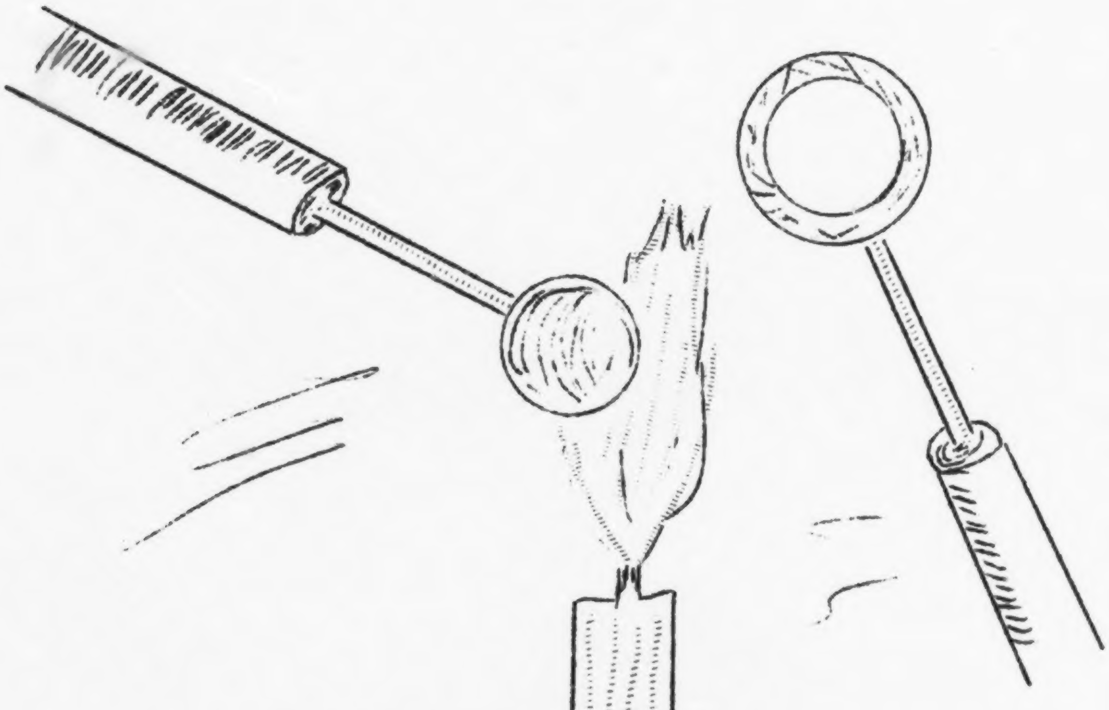
Take the ball and ring. Will the ball go through the ring?

The ball should barely pass through the ring when both are at room temperature.

1. If the ball is heated, will it pass through the cool ring?____________
2. If the ring is heated, will a hot ball pass through the hot ring?________
3. Will a cool ball pass through a hot ring?____________________________
4. How could the metal expand?______________________________________

Student
page 2





TEACHER DIRECTION P - 26

HEAT: WEIGHT AND VOLUME

Materials for groups of three:

1. Meter stick and pin (P-1)	6. One-hole stopper
2. 2 hooks	7. String (24 inches)
3. Ring stand	8. Alcohol burner
4. 8 washers (4 oz. each)	9. Plastic soda straw (fit rubber stopper.)
5. 500 ml flask	10. 250 ml beaker

This activity will make further use of the 'if - then' approach. Do not tell the students the expected outcome. Read the statement to the class, discuss it as long as there are questions.

Pass out P-26

IF MOLECULES ARE SEPARATED AS THOUGH THEY ARE BOUNCING BALLS, AND IF THE MOTION OF THE MOLECULES SPEED UP WHEN HEATED, THEN THE SUBSTANCE SHOULD GET BIGGER WHEN HEATED.

The following two experiments should demonstrate the effect of heat on volume

1. Assemble the apparatus by placing the pin through the hole in the middle of the meter stick and clamping the pin to a ring stand. Add cold water to the flask until the water level is to the neck of the flask. Attach the flask to one end of the stick with the string and balance with weights. If more water is needed, add until the stick is in balance. Mark the final cold water level on the flask. Replace the cold water with an equal volume of hot water. The hot water should be lighter.
2. Add water to a beaker until two-thirds full. Insert a glass tube into a rubber stopper and fit it tightly into the empty flask. Invert the flask and dip the end of the tube into the beaker of water. Heat the flask until several air bubbles appear. Then remove the burner and allow the flask to cool. Some water should be drawn up into the tube as the air cools and contracts.

STUDENT P - 26

HEAT: WEIGHT AND VOLUME

Materials for groups of three:

1. Meter stick and pin (P-1)
2. 2 hooks
3. Ring stand
4. 8 washers (4 oz each)
5. 500 ml flask
6. One-hole stopper
7. String (24 inches)
8. Alcohol burner
9. Plastic soda straw (fit rubber stopper)
10. 250 ml beaker

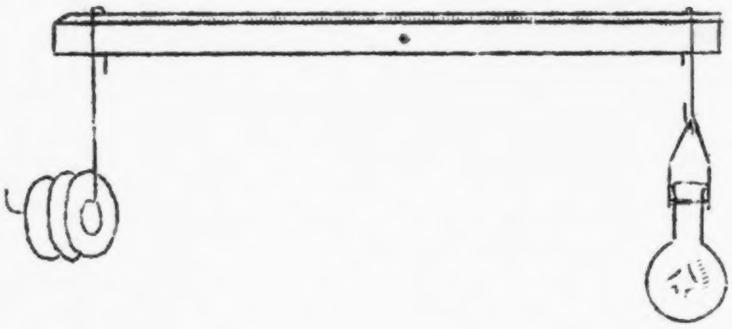
In this activity you are to consider two conditions, draw conclusions, and support or reject a prediction. The prediction may or may not be right.

PREDICTION:

_If_ molecules are separated by space as though they were bouncing balls, and _if_ the motion of the molecules speed up then heated, _then_ the substances should get bigger when heated. To find out if the volume increases when heated, try the two experiments below.

Suspend the meter stick at the mid-point from the ring stand. Add cold water to a flask until the water level is to the neck of the flask. Attach the flask to one end of the meter stick with a string and balance with weights. If more water is needed for balance, add water until the meter stick is in balance. Mark the final cold water level on the flask. Then pour out the cold water and replace it with an equal volume of hot water.

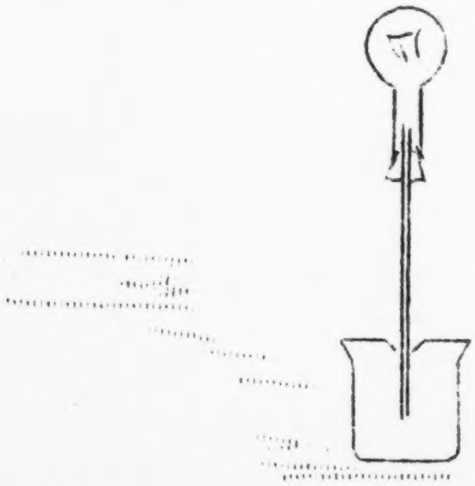
Student
page 2



1. Was the cold water heavier or lighter?__________________________

2. Why did the water expand when heated?__________________________

Add water to a 250 ml beaker until it is two-thirds full. Apply liquid soap or glycerine to a glass tube, insert the glass tube in a rubber stopper, and fit it lightly into an empty flask (full of air). Invert the flask and dip the end of the tube into the beaker of water. Heat the flask with an alcohol burner while holding the end of the tube under water until several air bubbles appear. Then remove the burner and allow the flask to cool, keeping the end of the tube in the water.



1. Where did the bubbles come from?______________________________________

2. Why did the air expand when heated?____________________________________

3. Why was the water drawn up into the tube?______________________________

TEACHER DIRECTION

P - 27

CONDUCTION, CONVECTION, RADIATION

This activity is a reading activity on the methods of transferring heat. The teacher may want to read it aloud to the students or let them read it alone and then read it with them.

Many investigations can be planned to reinforce the reading materials. The students familiarity with heating and cooling can aid in planning activities outside the classroom. Examples are measuring temperatures of different colored liquids, of the inside of cars with different colored tops, and of the temperature of the air above sidewalks and lawns, et al. The energy from the sun furnishes us with all of our heat and light, neglecting any small contribution from all other stellar bodies. Pass out P-27

CONDUCTION, CONVECTION, RADIATION

Let's go swimming in John's swimming pool. Get your swim suit, towel, and hat and let's go. By the way, don't forget the sunburn lotion -- we'll need it. The sun is high and it's really hot outside today. Wish I had my sunglasses to reflect some of the light and heat.

"Hey, John, you must be crazy. You painted the diving board black and it's so hot I can't even touch it. Don't you know that dark colors absorb more heat than light colors?" Oh, well, anyone can make a mistake. John knew that people use white shingles on their houses because in the summer they are cooler, but ------

Swimming makes me hungry so I brought along some hot dogs. John has a charcoal pit and some metal rods that we can use. How about a weiner roast? The heat is really radiating from the sun today. It's amazing how so much energy can get from the sun to the earth, especially since it has to travel through outer space.

"That's a pretty good fire you got there, Jack. Won't it go out unless you fan it? The wind isn't blowing today." Jack watched Hoss and Little Joe build a fire one time, and he figured out that heat rises when a fire is built; cool air from all sides rushes in pushing the hot air from the fire upwards. This air circulation is called convection and, if you think a minute, convection explains why the wind blows. This is also why we direct the cool air of our air conditioner toward the ceiling. Hot air is lighter than cool air. So the hot air will be pushed up toward the ceiling by the cool air.

"Hey, John, I though you were crazy, but now I know you are stupid. Your metal rods that we are using to roast the hot dogs with are getting hot. We can't hold them." John wasn't really stupid, he just forgot to get the wood handles for the rods. He knew that metal conducts heat and that some materials are better conductors than others. Wood doesn't conduct heat very well. That's why it is used for a handle.

Student
page 2

Let's try to remember some of the things we learned from this party. I'll list a few and you try to remember how it happened.

1. Dark colors absorb more heat than light colors. Light colors radiate more heat than dark colors.
2. Heat can travel by radiation which does not require any help from solid, liquid or the wind (gaseous materials).
3. Heat can travel by convection which is caused by the air circulating. Hot air is lighter than cool air. Hot air rises and cool air settles to the ground due to gravity.
4. Heat can travel by conduction where it is passed through a solid piece such as metal. All solids are not good conductors.

TEACHER DIRECTION P - 28

HEAT OF VAPORIZATION

Materials for groups of three:

1. Two 250 ml beakers
2. Two ring Stands
3. Two gas burners
4. Two thermometers

The heat of fusion is the quantity of heat required to change a solid to a liquid without changing the temperature. The heat of fusion for ice is 80 calories per gram of ice. The change of state of ice from a solid to a liquid will take place at 0°C (32°F). This ice will absorb heat energy (80 cal./gram) until the molecules rearrange themselves to become a liquid, then the temperature will increase until the boiling point is reached. The calorie is defined as the quantity of heat energy required to increase the temperature of one gram of liquid water one degree centigrade. This means, if you have one gram of ice at 0°C, the molecular structure will prevent the solid from changing into a liquid until 80 calories of heat is absorbed by the molecules. When the water is in the liquid state, the temperature of water will rise 1°C when a calorie of heat energy is absorbed provided the water remains in the liquid state. The water temperature will continue to increase as heat energy is absorbed until it reaches 100°C. The temperature of the water will not increase above 100°C in an open beaker, but will continue to absorb energy. If the one gram of water is considered, at 100°C, the molecules will prevent the forming of water vapor until 540 calories of heat energy is absorbed; at this time the energy level in the molecules are so great the bonds break and the water escapes as a gas. The quantity of heat energy absorbed at 100°C, 540 cal./gram, which changes the water molecule relationship by breaking the bonds between the molecules making the liquid change to a gas, is called the heat of vaporization of water. Note that the Centigrade scale must be used.

The students need to understand the definition of a calorie. A demonstration using 100 ml of water in a 250 ml beaker, an alcohol burner and a thermometer is adequate. Set up the demonstration apparatus, for a class discussion. Write the definition of a calorie on an acetate, but make no reference to it until the demonstration is complete.

LET'S TALK ABOUT A DEFINITE QUANTITY OF HEAT ENERGY CALLED A CALORIE. BUT FIRST, WHAT MAKES THE TEMPERATURE OF SOMETHING RISE? (Absorbs heat). HOW MUCH HEAT MAKES WATER TEMPERATURE RISE 1°C? Calorie.

Do not give the students a technical definition of calorie. Time is not a factor in calories. Start the demonstration. Make your calculations on the acetate under the definition of calorie. Have a student stir the water and tell you when the temperature rises 1°C. This will be 100 calories to raise the temperature 1°C. Make up problems such as, how many calories are needed to raise 50 grams of water 2°C? (100 calories.)

The student activity for heat of fusion and heat of vaporization will be more meaningful if calories are well understood. The "if - then" prediction will again be used. Follow the same procedure as used in P-26.

IF MORE HEAT IS REQUIRED TO CHANGE THE STATE OF AN SUBSTANCE THAN TO CHANGE THE TEMPERATURE OF THE SUBSTANCE, THEN UPON HEATING, THE ICE AND RESULTING ICE WATER AT 0°C WILL REMAIN AT 0°C UNTIL THE ICE IS MELTED. THEN, UPON CONTINUED HEATING, THE WATER TEMPERATURE WILL RISE TO 100°C AND REMAIN UNTIL ALL THE WATER IS CHANGED TO STEAM. (Discussion).

Pass out P-28.

The students are to complete the table and graph the results.

Place ice in two 250 ml beakers and add water until ½ full. Carefully stir with a thermometer until the liquid reaches 0°C. Remove the ice from one beaker, replacing the lost volume of water by adding ice water until both beakers contain an equal volume. Heat both of the beakers with two gas burners that are adjusted to produce the same amount of heat. Record the temperature each minute over a 30 minute period, record the results and draw a graph. On completion of the activity, clinch the concepts in a class discussion.

STUDENT

P - 28

HEAT OF FUSION

HEAT OF VAPORIZATION

Materials for groups of three:

1. Two 250 ml beakers
2. Two ring stands
3. Two gas burners
4. Two thermometers

The heat energy a substance absorbs makes the temperature rise. Sometimes, however, the temperature does not rise even when a great deal of heat is absorbed. The calories, the amount of heat energy, absorbed by the molecules determine if a substance remains a solid, liquid, or gas. When heat is being absorbed one of two things will happen: (1) the temperature will rise and the phase (solid, liquid, gas) will not change, or (2) the temperature will **stay the same** and the phase (solid, liquid, gas) will change. The amount of heat required to change a solid to a liquid without changing the temperature is the heat of fusion. The amount of heat required to change a liquid to a gas without changing the temperature is the heat of vaporization.

This activity will show these relationships. You are to read the directions, complete the activity, record and graph the data.

If more heat is required to change the phase of a substance than to change the temperature of the substance; then upon heating, the ice and resulting ice water at 0°C will remain at 0°C until the ice is melted; then, upon continued heating, the water temperature will rise to 100°C and remain until all the water is changed to steam.

Set up two ring stands with two burners adjusted to produce equal amounts of heat intensity.

Number the beakers 1 and 2, then add ice and water to the two beakers until the water level is equal in both beakers -- about half full. Stir the ice water until they reach the freezing point, 0°C. Remove the ice from the first beaker and place it in the second beaker. Pour water out of the second beaker into the first

Student
page 2

beaker until the water levels are the same.

Place both beakers, at the same time, on the ring stand, stir gently while taking temperatures each minute for twenty minutes. Record the temperature in the Table. After completion of the table, graph the results and interpret the data.

TEMPERATURE AND HEAT ABSORPTION

Temperature each minute

MINUTES --	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. No Ice																				
2. With Ice																				

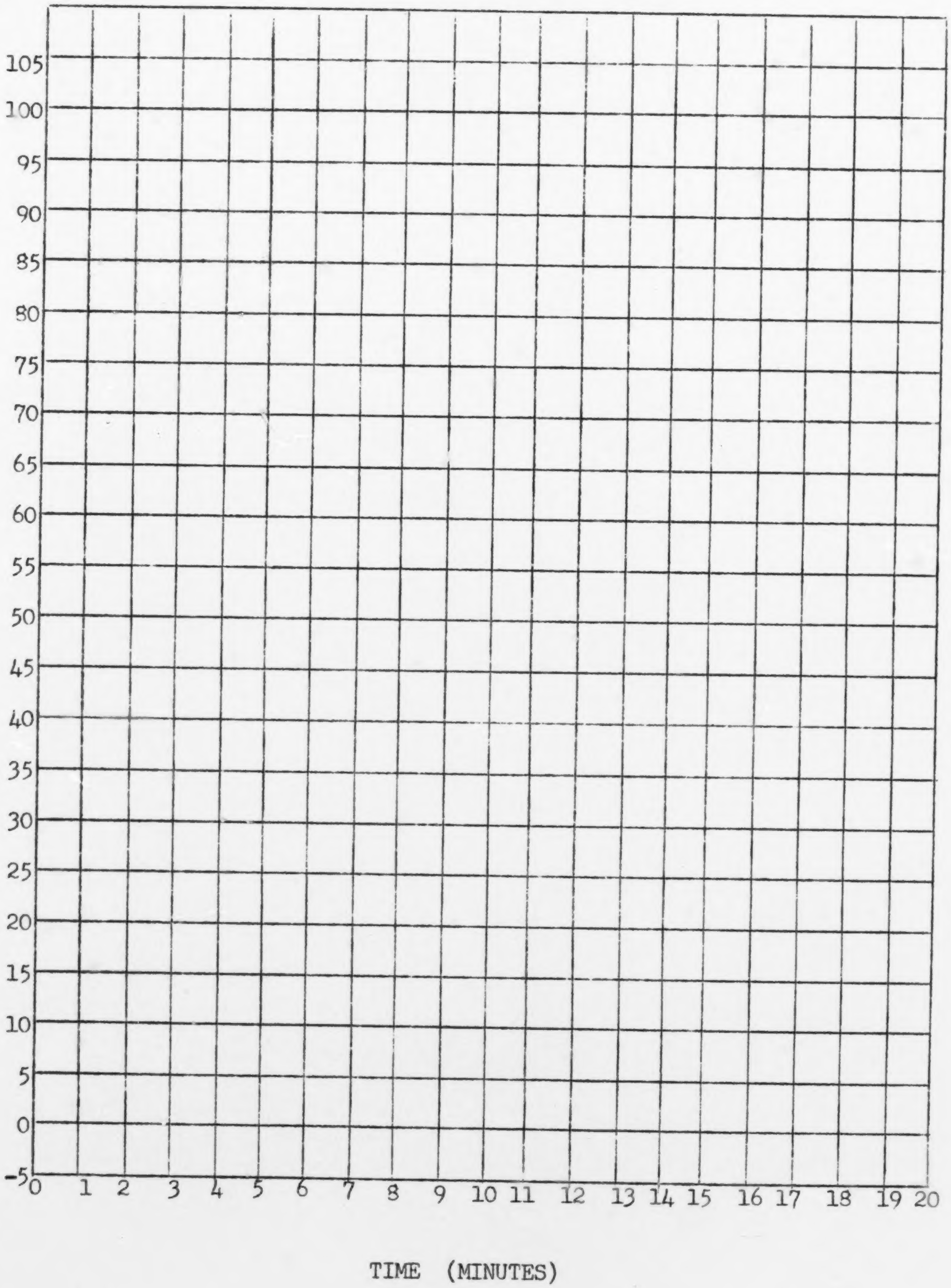
The graph will have two lines. Label the line 1 and "no ice", and label line 2 as "with ice".

1. How many minutes did it take the temperature in the beaker with "no ice" to start rising?____________________
2. How many minutes did it take the temperature in the beaker "with ice" to start rising?____________________
3. Which beaker absorbed the most heat?____________________

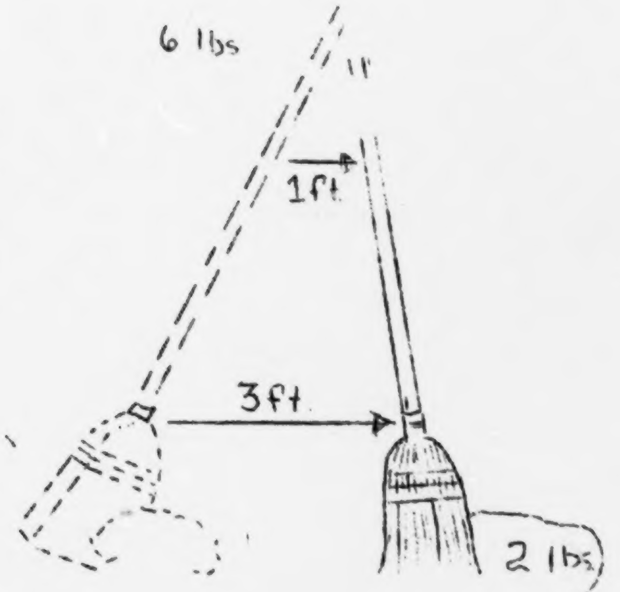
   How do you know?____________________

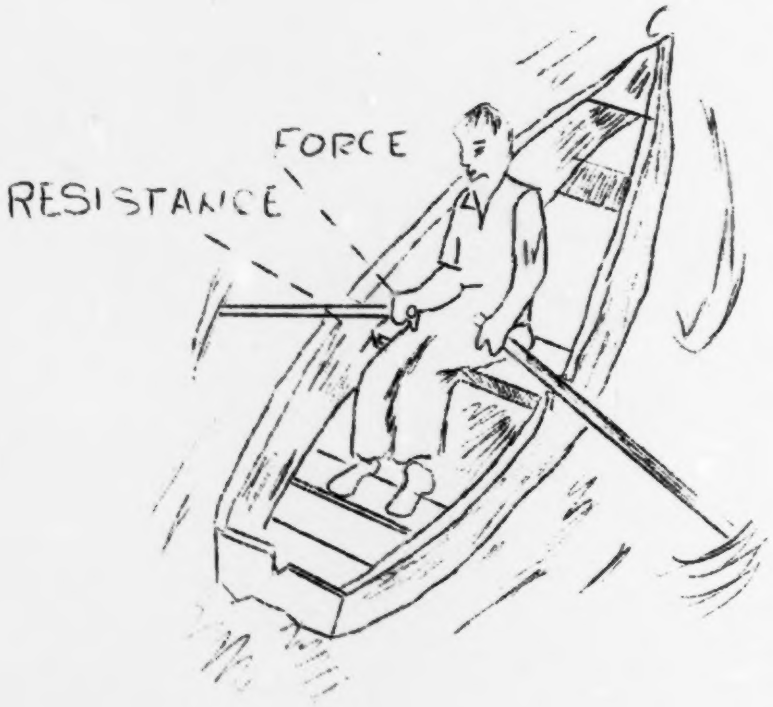
   ____
4. Label the parts on the graph that represent the heat of fusion, temperature rise, heat of vaporization, ice, liquid, and the temperature where steam forms.
5. Does your data support or reject the prediction? Explain in detail.

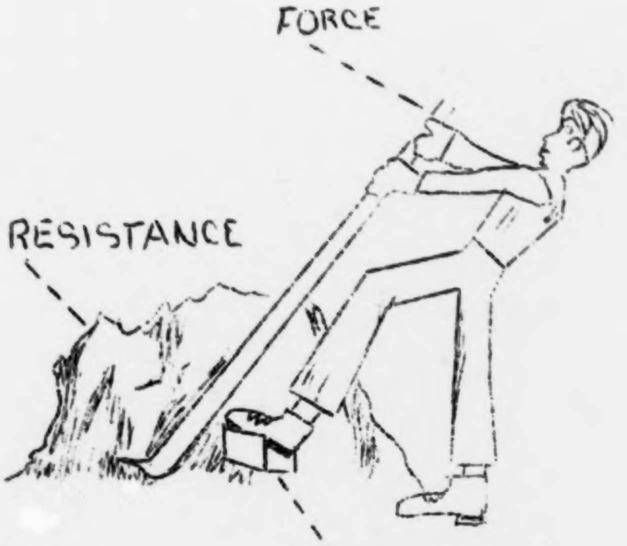
Student
page 3

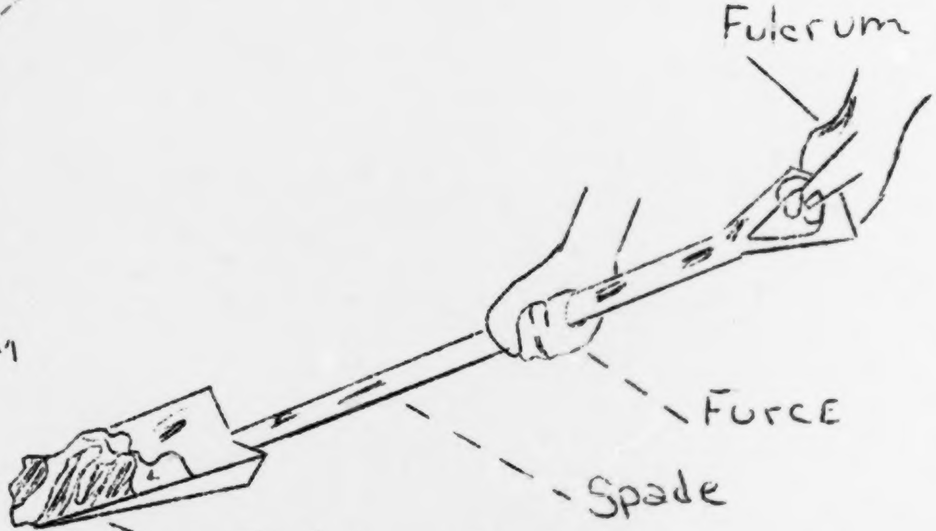


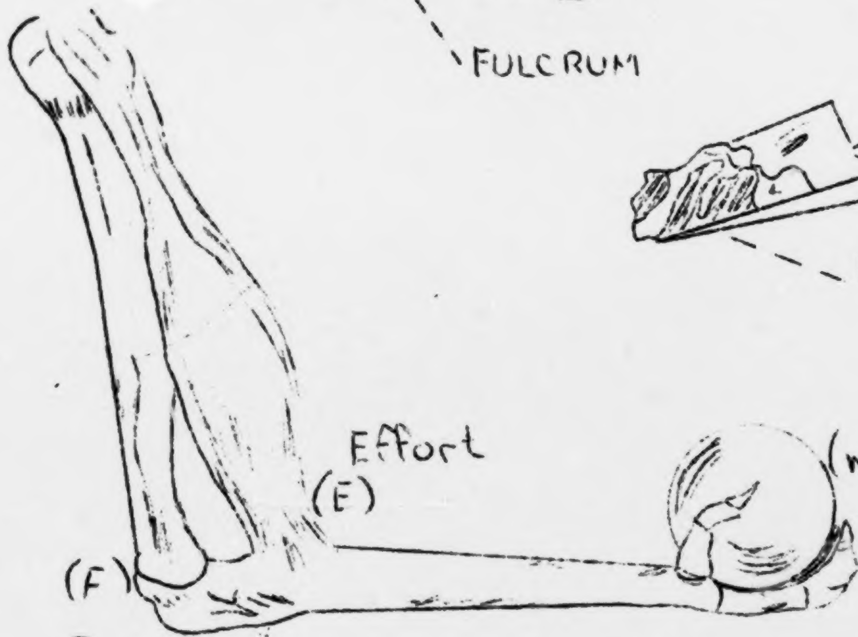
ITEM	QTY	COST
Supplies		
Fulcrum bracket, Each	12	2.40
Hardboard, 5" x 13", Each	12	5.40
Hero's engine apparatus, Each	12	7.20
Hook, Each	12	.45
Lever, wood ruler, Each	12	2.70
Lever holder, Each	12	2.70
Plastic tube, Each	12	.30
Pulley block, Each	12	7.20
Pulley wheel, single, Each	36	4.50
Spacer, brass, Each	36	.45
Supports, slotted hardboard, Each	24	4.20
Truck, 4 oz, Each	12	7.20
Wing nut, Each	36	.90
GLASSWARE		
Beaker, 250 ml, Each	24	7.44
Bottle, gas collecting, 8 oz, Each	12	.80
Cylinder, graduated, 50 ml, Each	12	16.70
Flask, erlenmeyer, 250 ml, Each	12	4.92
Flask, florence, 500 ml, Each	12	9.12
Funnel, short stem, 75 mm, Each	12	8.04
Jar, pint, w/lid	12	N/C
Lamp, alcohol, 4 oz, Each	12	5.40
Medicine dropper, Each	12	.50
Mortar and pestle, Each	12	17.16

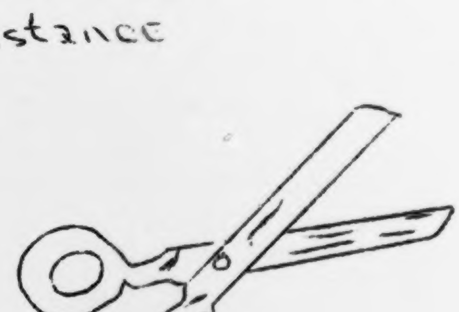

6 lbs
1'
1ft
3ft
2 lbs


FORCE
RESISTANCE

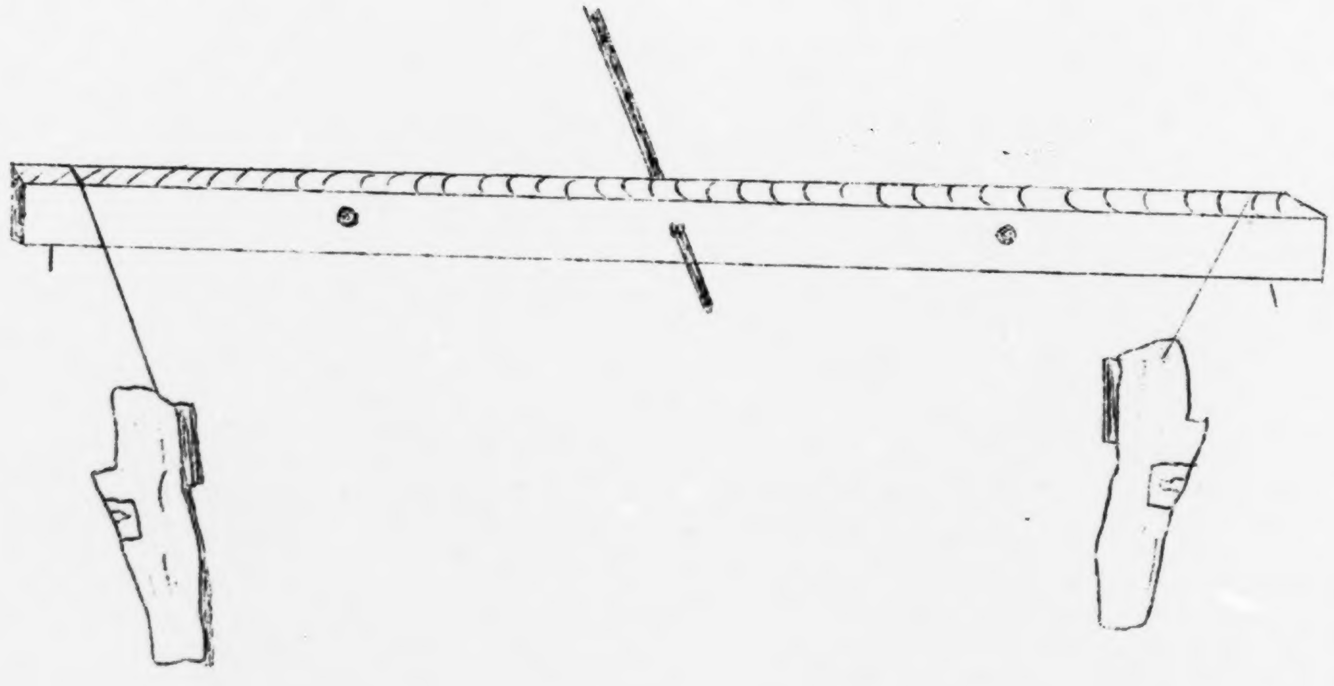

FORCE
RESISTANCE
FULCRUM


Fulcrum
Force
Spade
Dirt (resistance

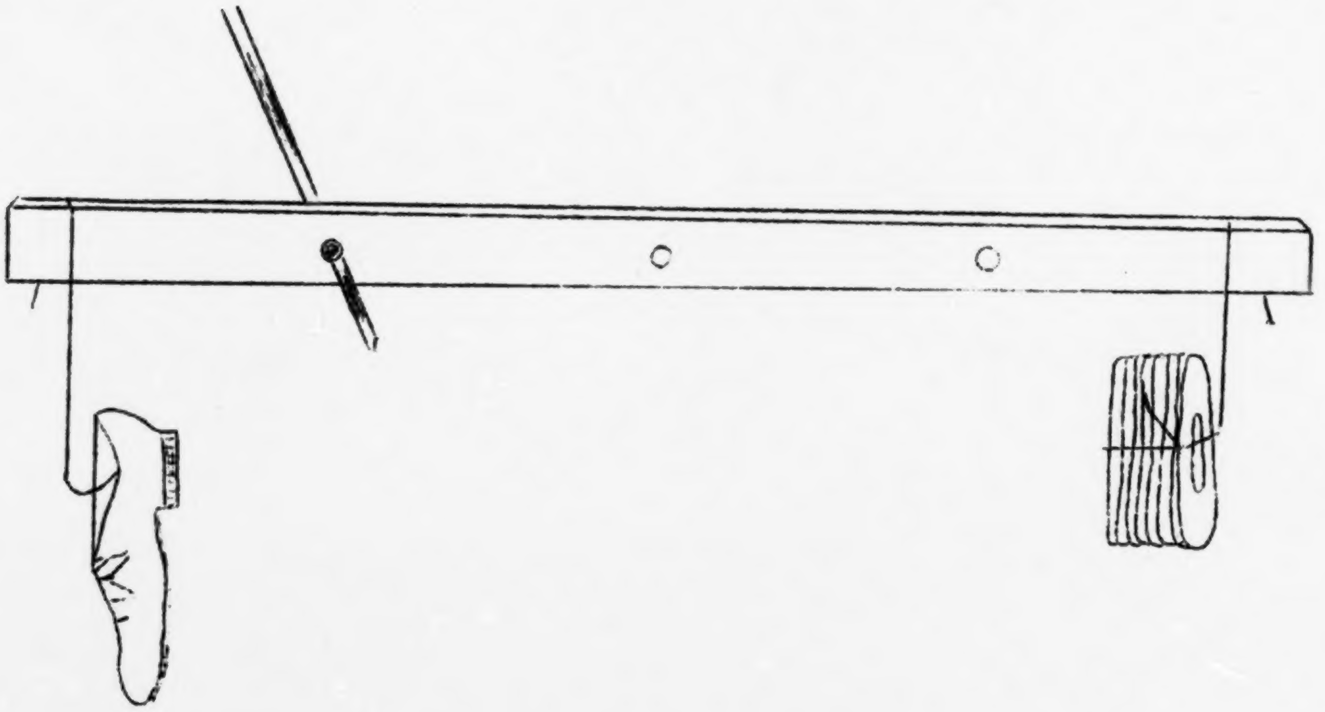

Effort
(E)
(W)
Weight
(F)
FULCRUM


Scissors

P-1



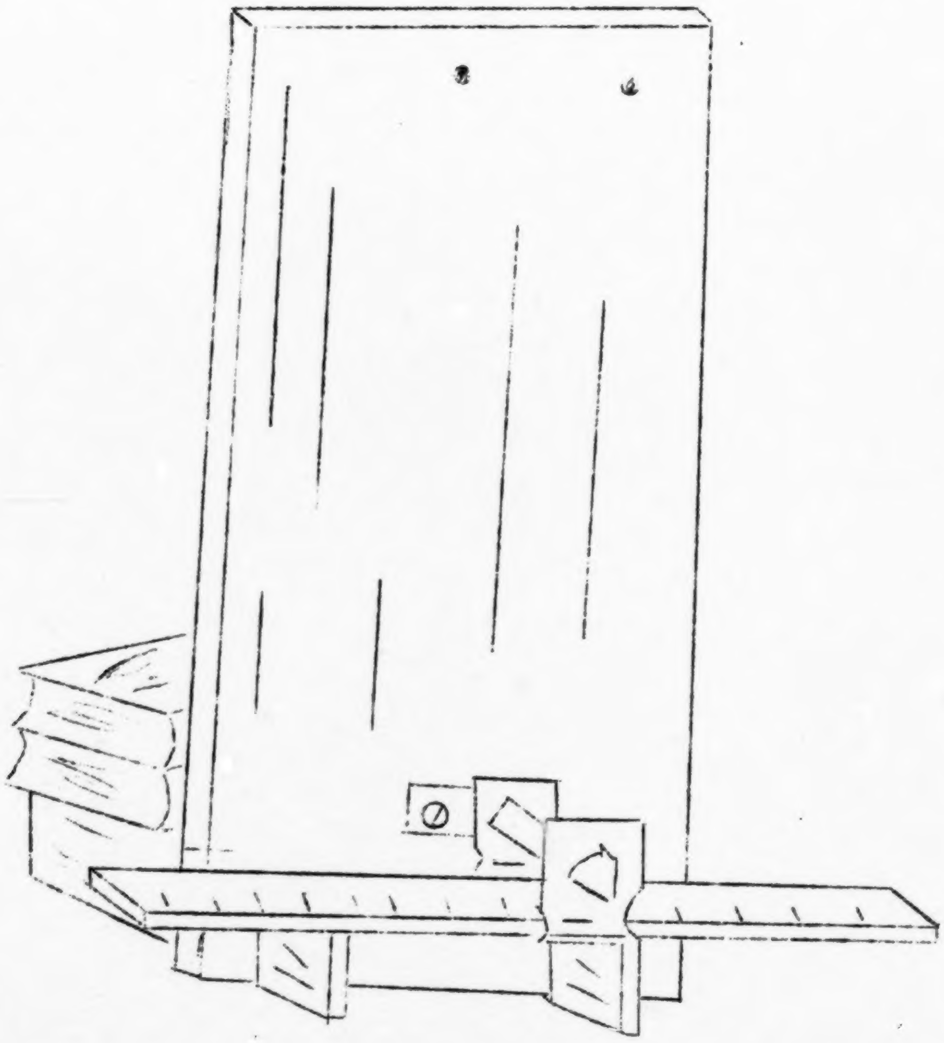
P-2



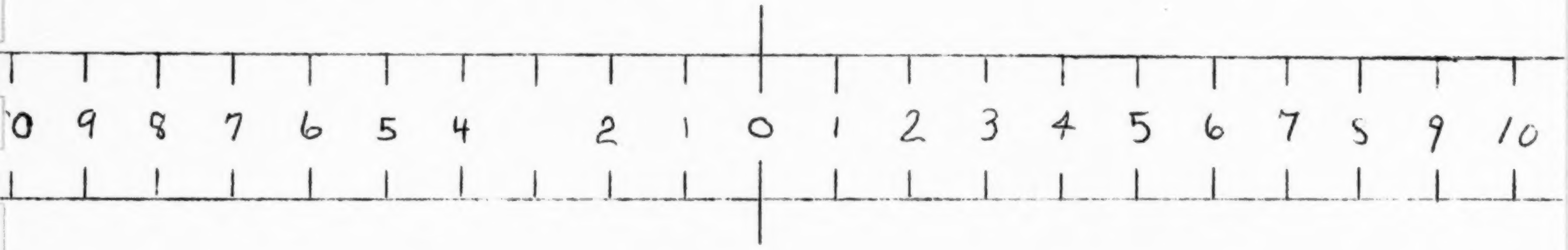
P-2A

GROUP NO.	HEAVIEST SHOE	LIGHTEST SHOE

P-4



P.4, P-5, P-6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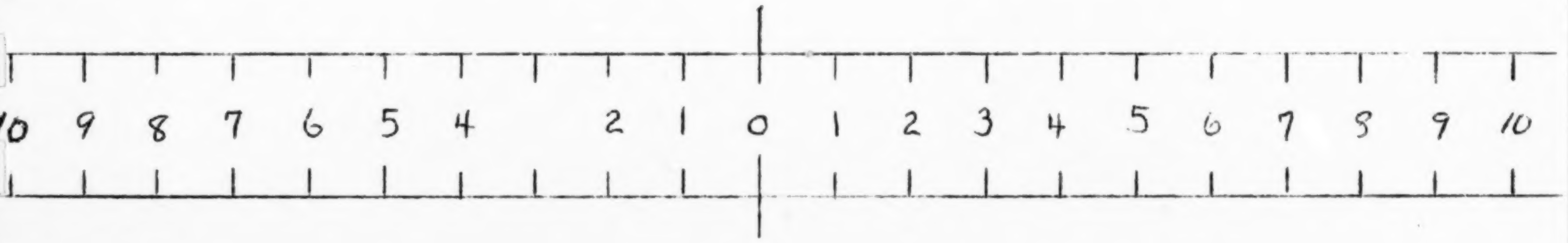
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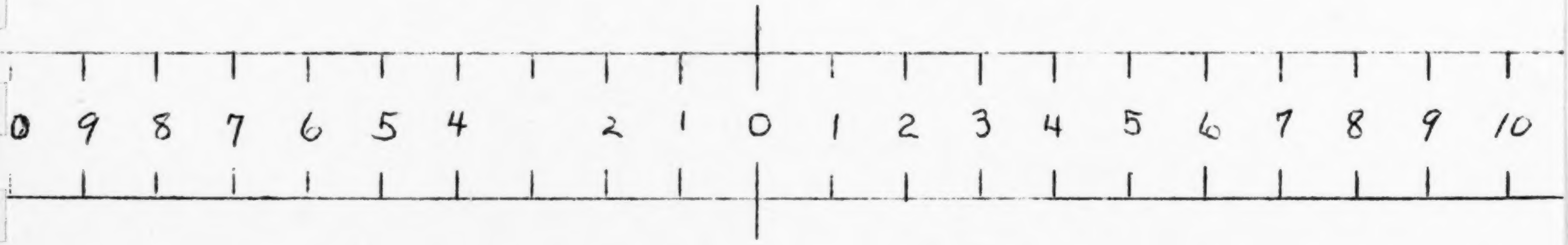
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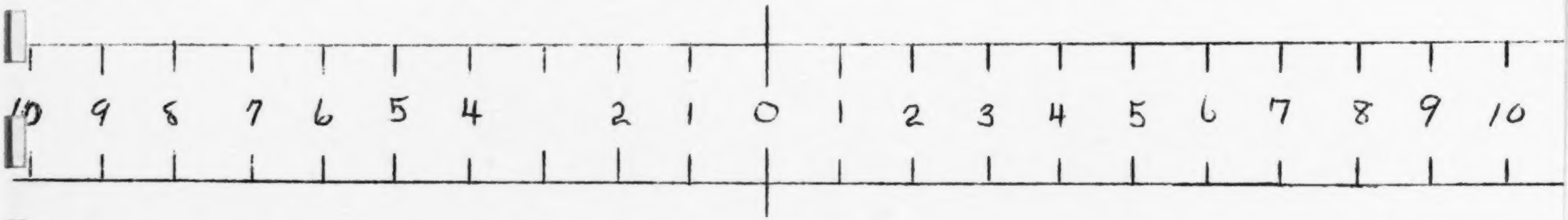

10 9 8 7 6 5 4 2 1 0 1 2 3 4 5 6 7 8 9 10

P6

Number	Left Side			RIGHT Side		
	Weight	Position	Moment	Weight	Position	Moment
1	1	8		1	3	
	xxx	xxx	00	1	5	
	▨	▨		▨	▨	
2	1	10		1	7	
	xxx	xxx	00	1	3	
	▨	▨		▨	▨	
3	1	4		1	12	
	1	8		xxx	xxx	00
	▨	▨		▨	▨	
4	1	14		1	6	
	xxx	xxx	00	1		
	▨	▨		▨	▨	
5	1	14		1	5	
	xxx	xxx	00	1		
	▨	▨		▨	▨	
6	1	3		1		
	1	8		xxx	xxx	00
	▨	▨		▨	▨	
7		5		1		
	1	9		xxx	xxx	00
	▨	▨		▨	▨	
8	1			1	3	
	xxx	xxx	00	1	6	
	▨	▨		▨	▨	

P-7

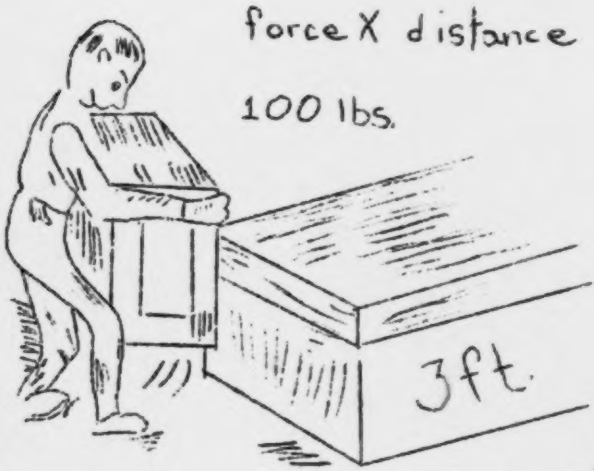
WORK=

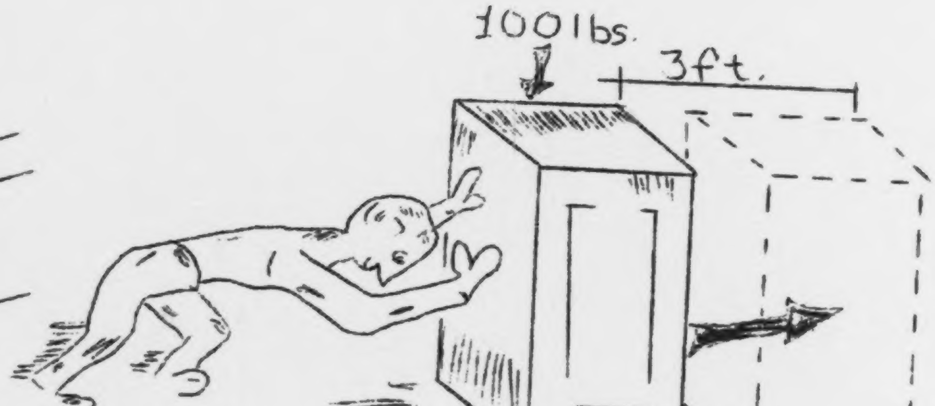
OBJECT	DISTANCE	FORCE POUNDS	WORK FOOT-POUNDS
1 Book	1 Foot		
1 Book	2 Feet		
1 Book	3 Feet		
2 Books	2 Feet		
2 Books	4 Feet		
1 Shoe	2 Feet		
1 Shoe	4 Feet		
1 Chair	1 Foot		

WORK=_____

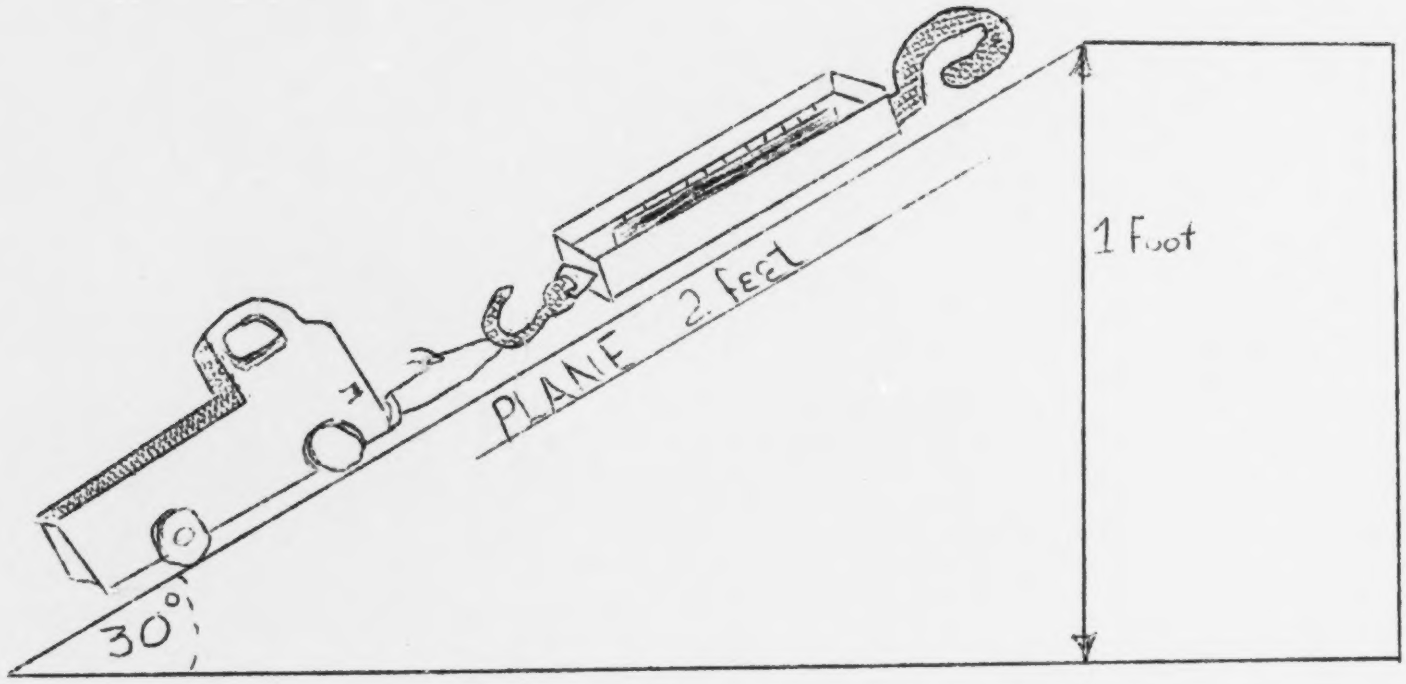
force X distance

100 lbs.

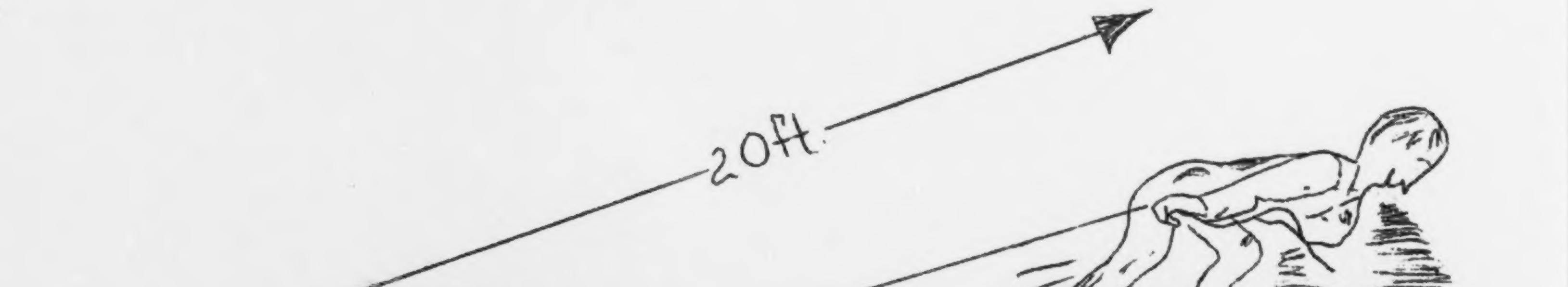




P-8

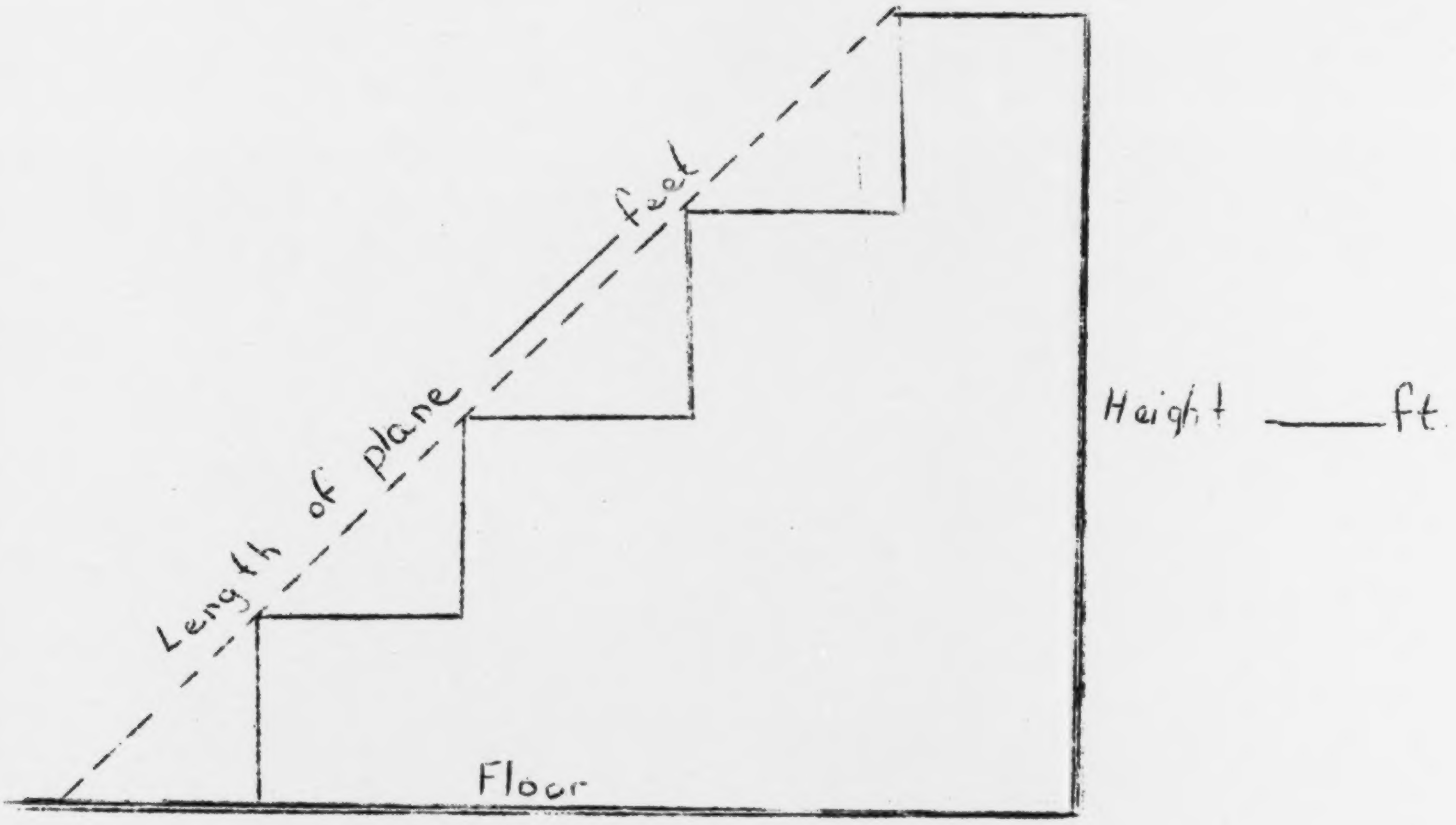

1 Foot
PLANE 2 feet
30°

INCLINED PLANE


20ft.
216lbs.
PLANE
10ft.

DP

P-9


Length of plane ______ feet
Height ______ ft.
Floor

P-9A

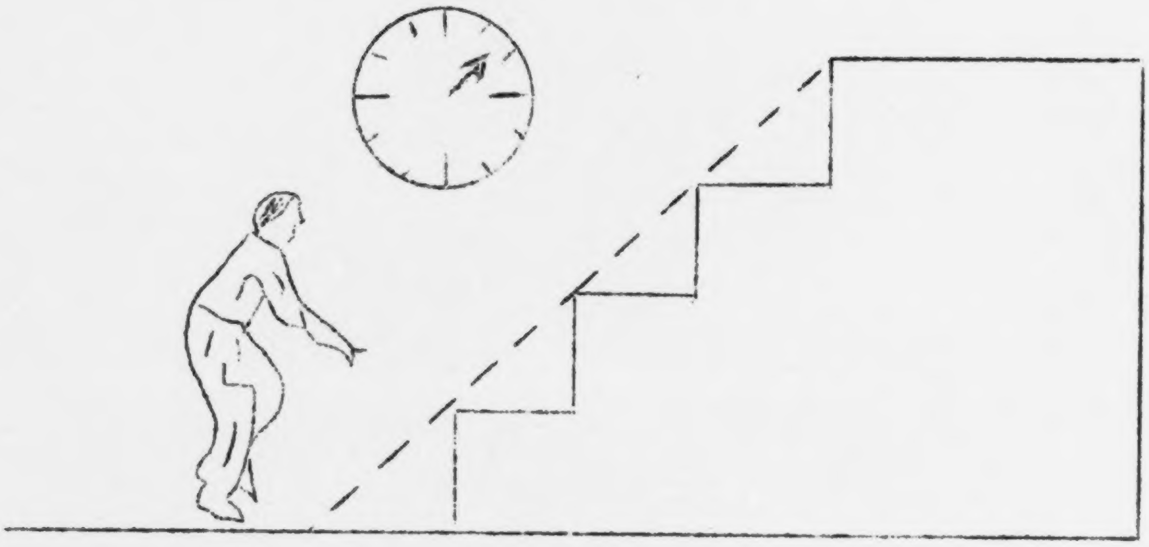
HEIGHT of stairs	RESISTANCE Weight of runner	WORK foot-pounds

Distance times Resistance = Work

WORK	LENGTH OF PLANE feet	EFFORT FORCE pounds

Work divided by Length = Effort

P-10



HEIGHT__________

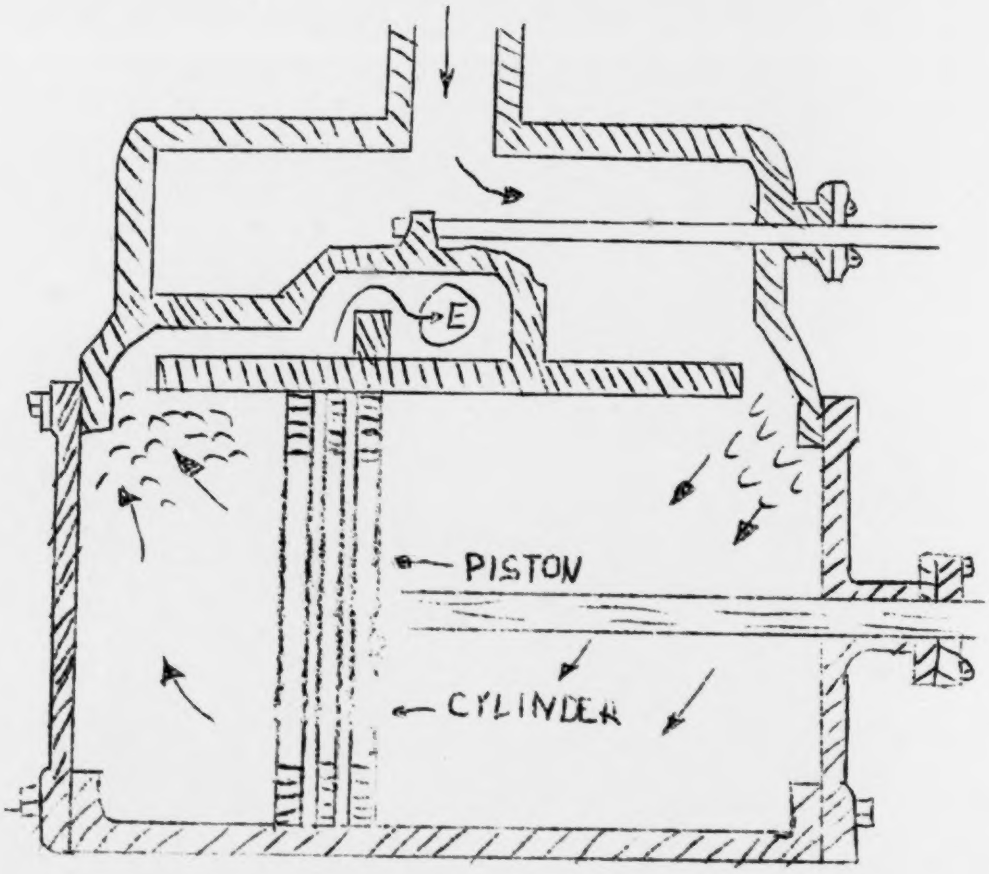
HEIGHT OF STAIRS	RESISTANCE WEIGHT OF RUNNER	WORK FOOT - POUNDS

Distance times Resistance = Work

WORK (from above)	TIME (seconds)	POWER foot - pounds / sec.

Work divided by Time = Power

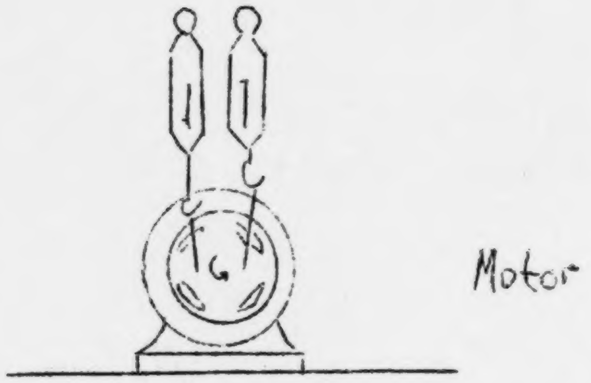
P-12

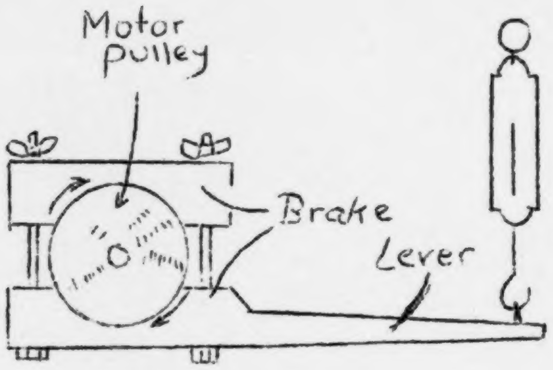

E
PISTON
CYLINDER

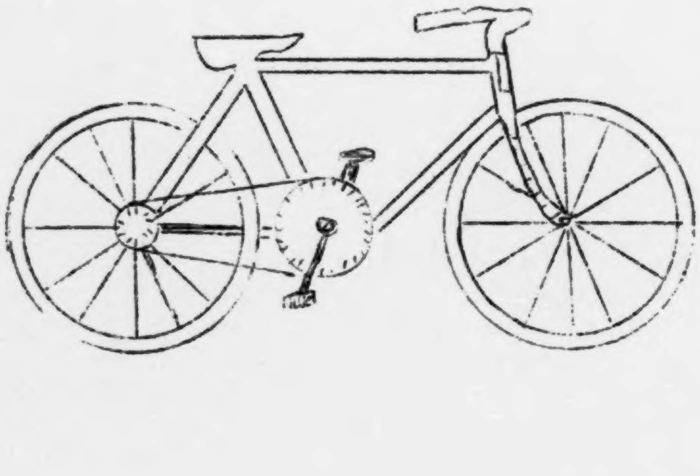
STEAM ENGINE

DP.

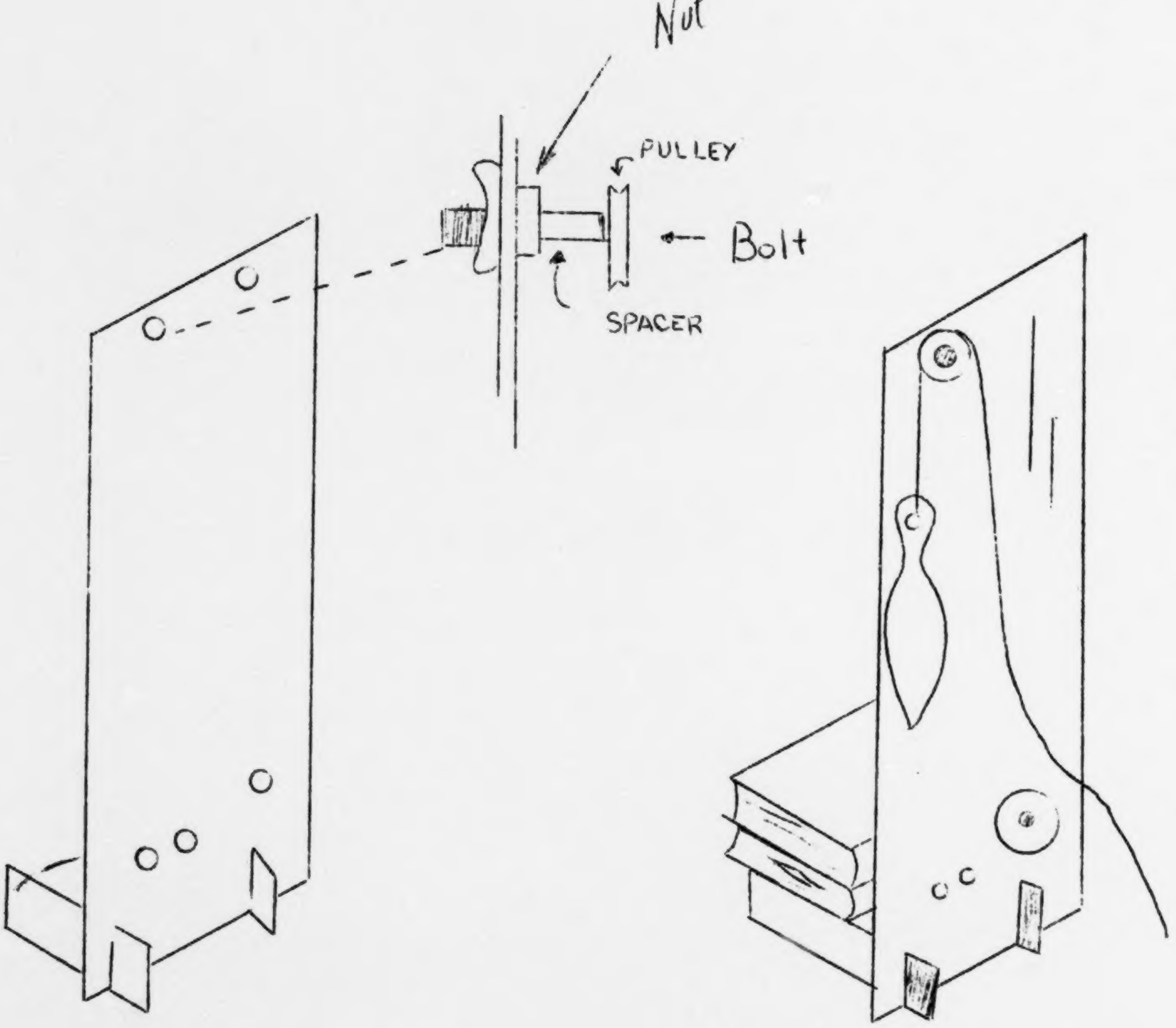
P.12A




Motor pulley
Brake
Lever



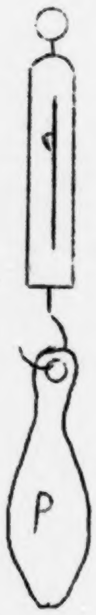
P-13


Nut
PULLEY
Bolt
SPACER

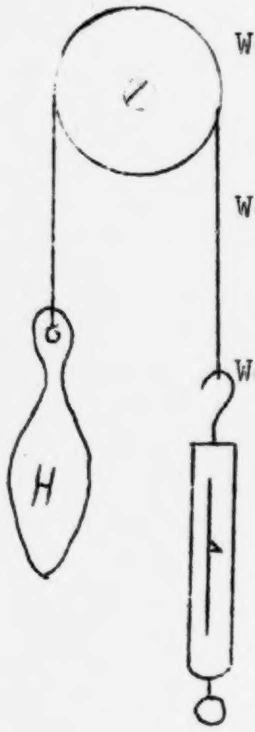
P-13A

1

WEIGHT__________



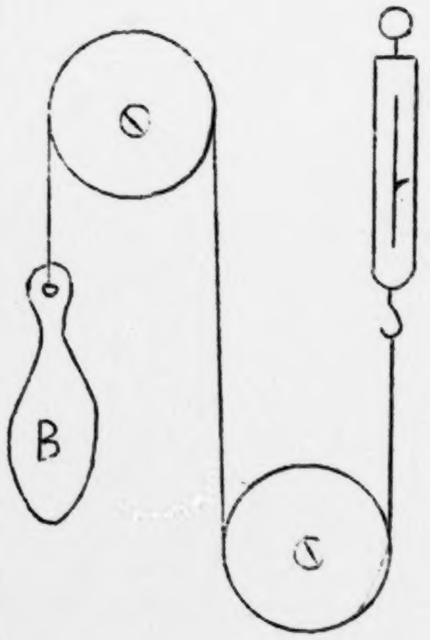
2



Weight__________
going up

Weight__________
going down

Weight__________
average

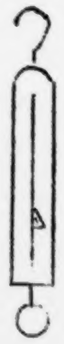


WEIGHT________
up

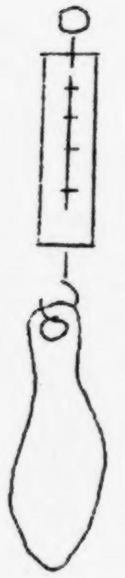
WEIGHT________
down

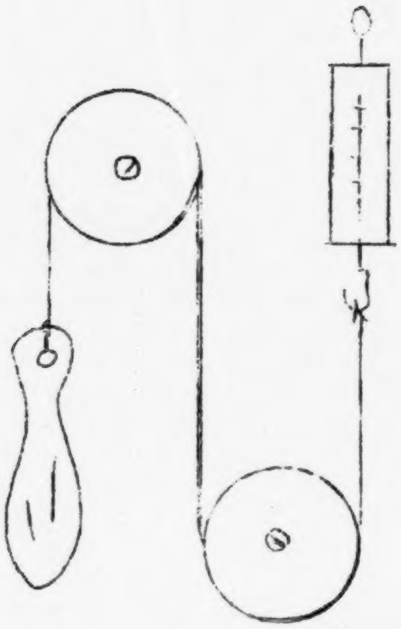
WEIGHT________
avg.

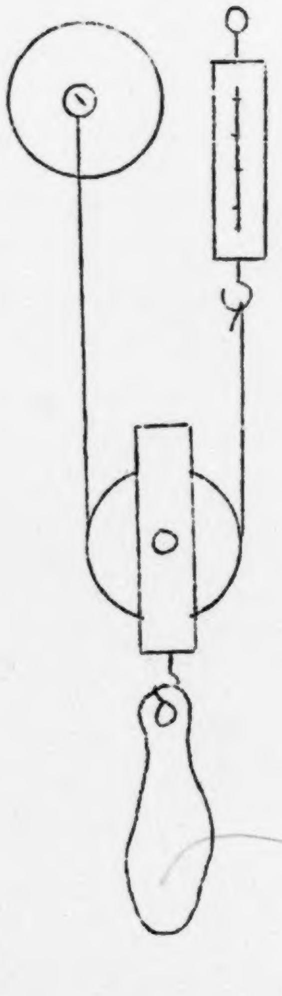
WEIGHT__________

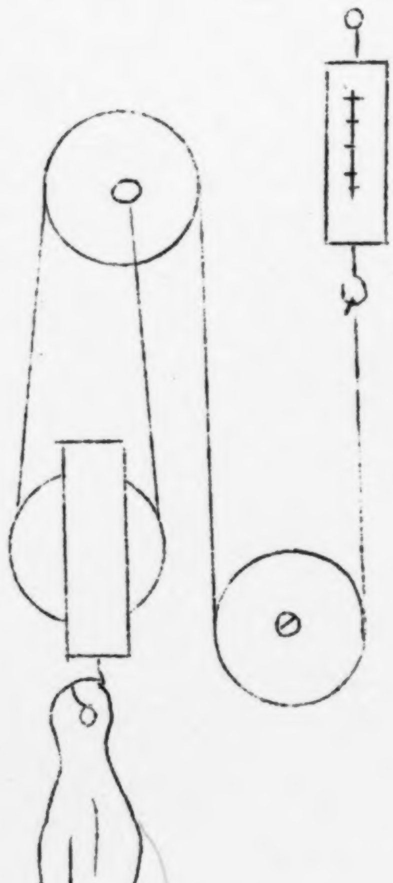


P-14

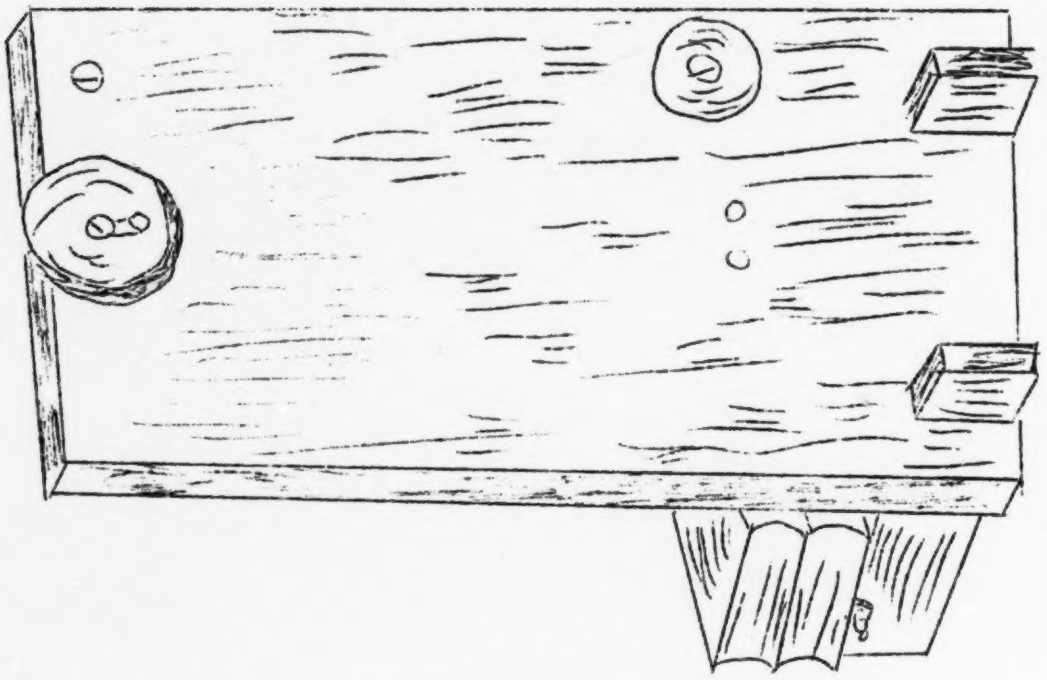


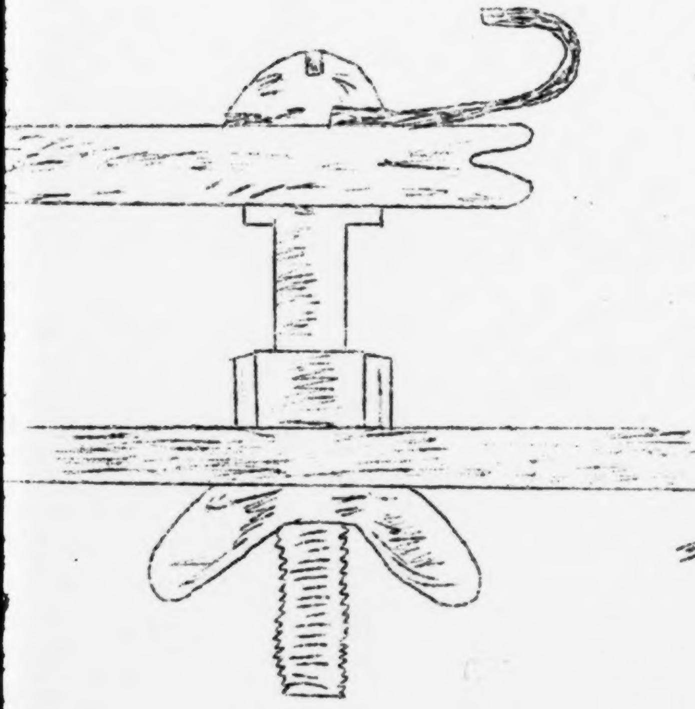


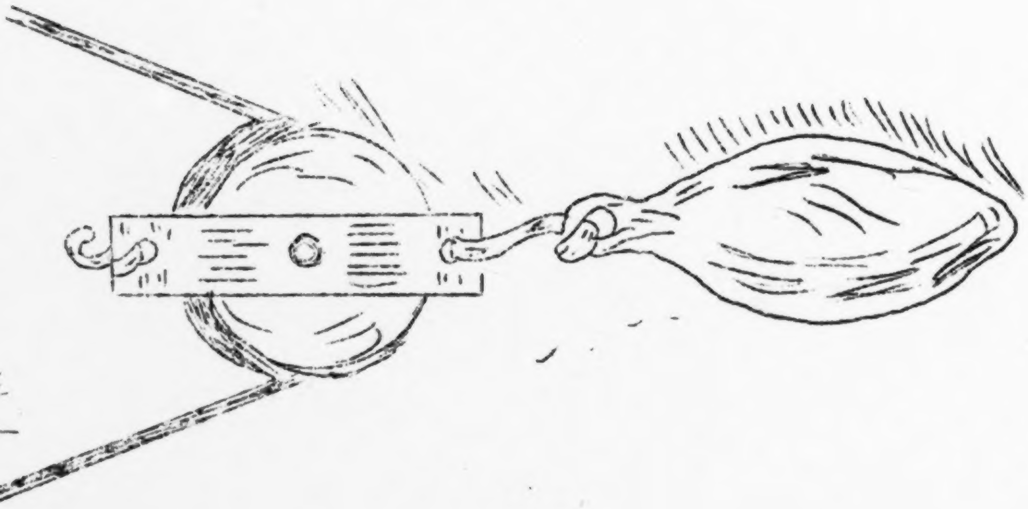


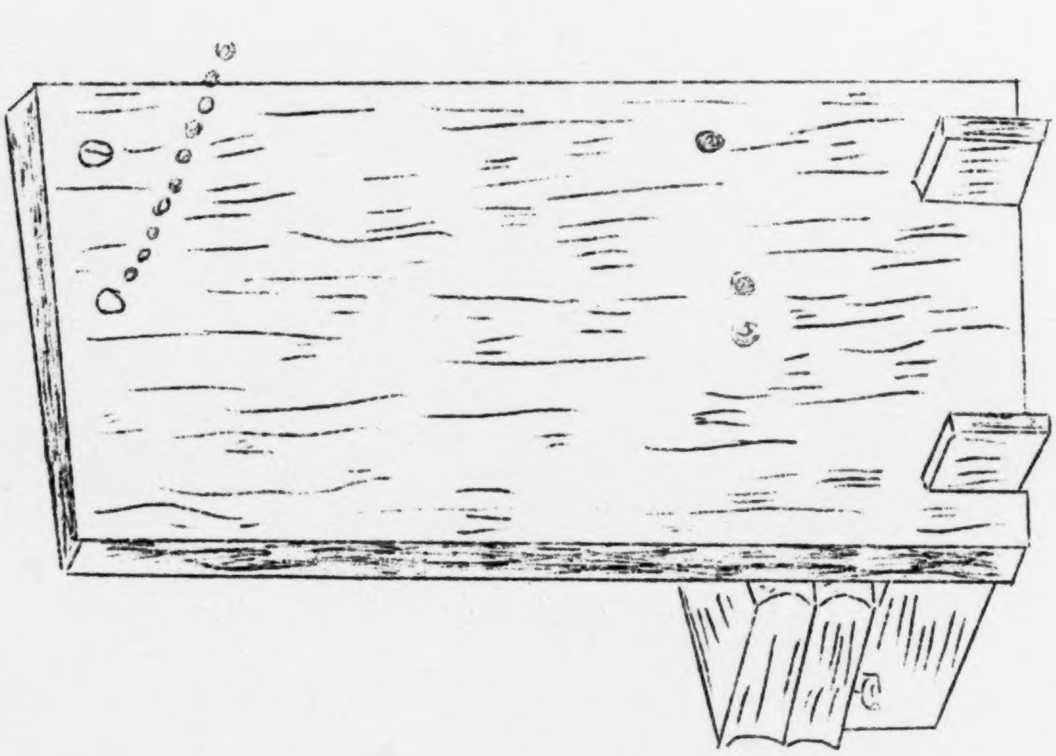


P-14

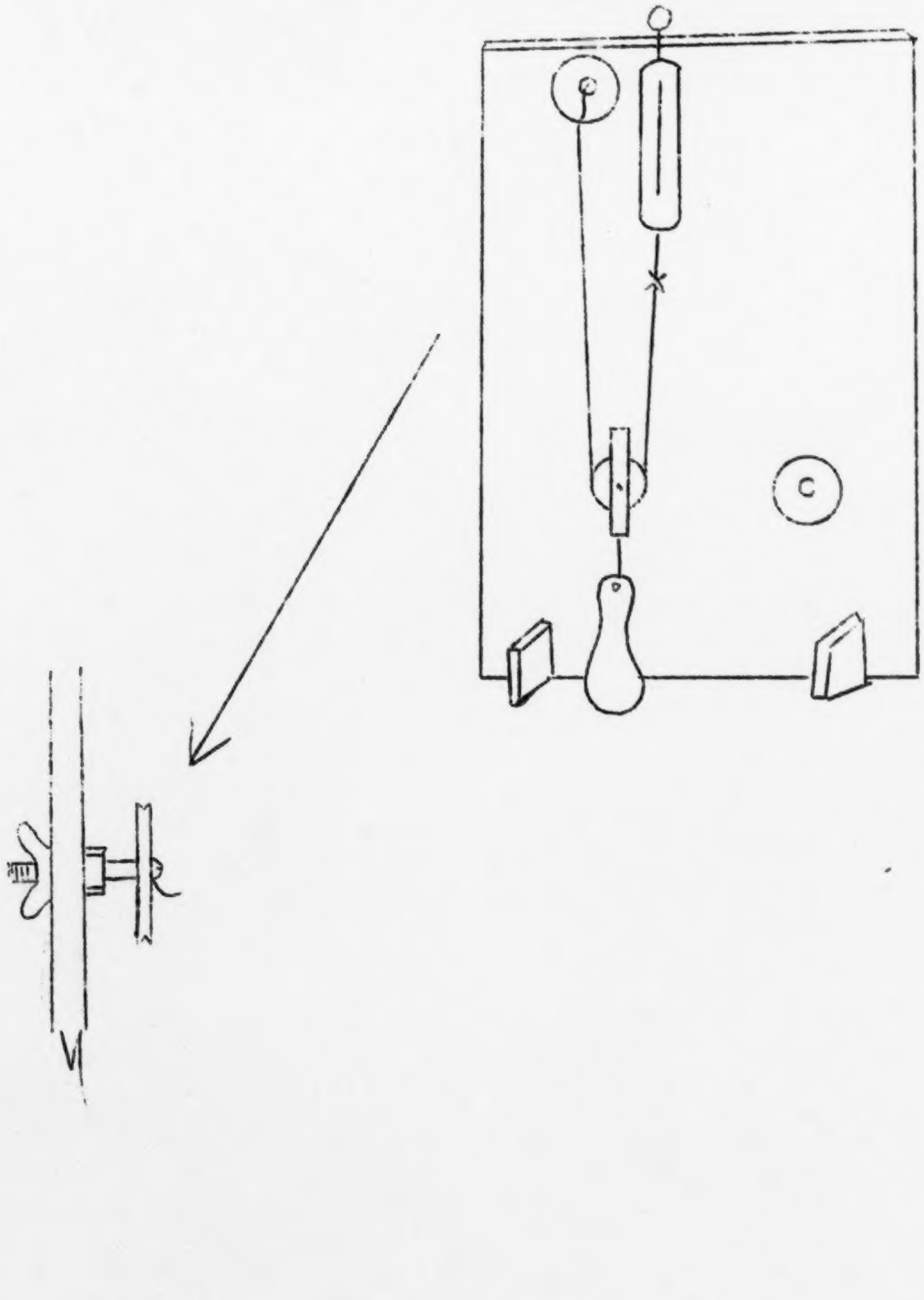








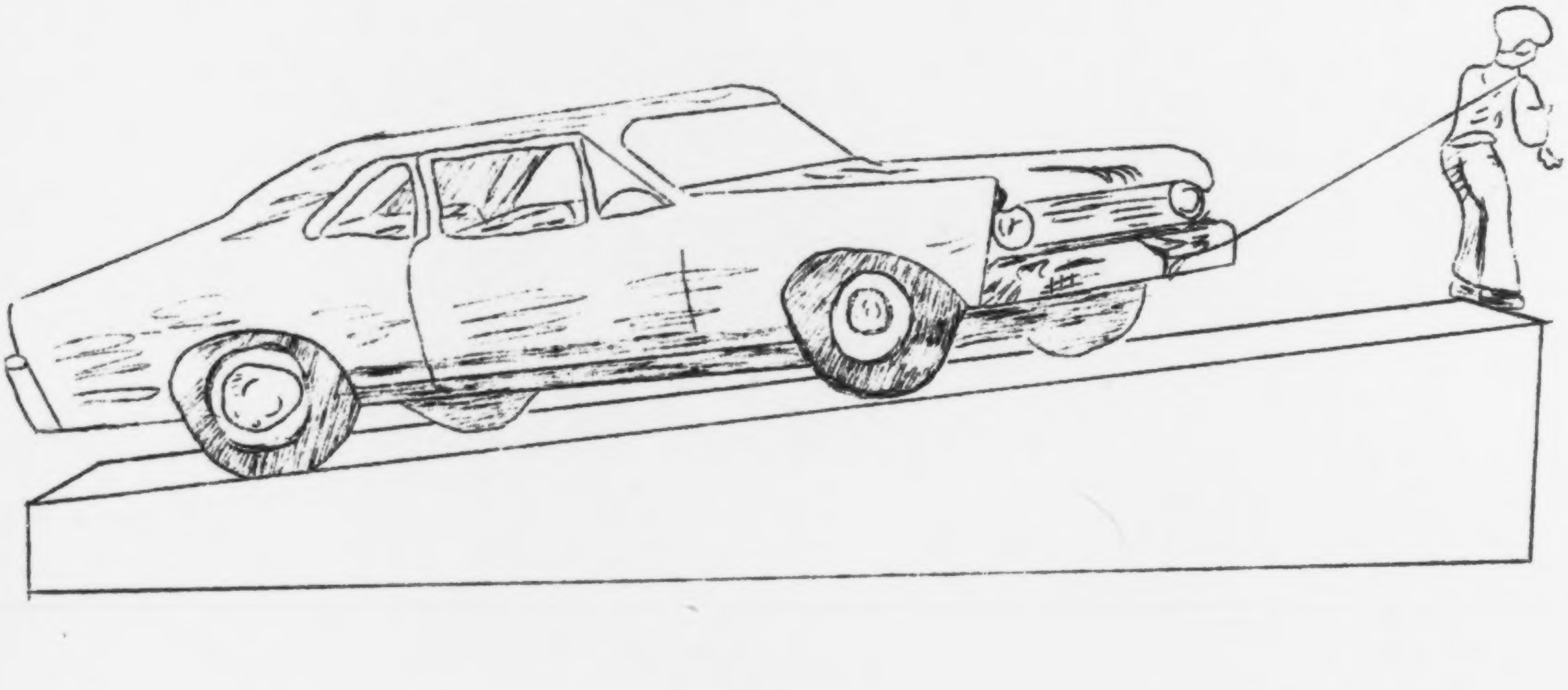
P-14A

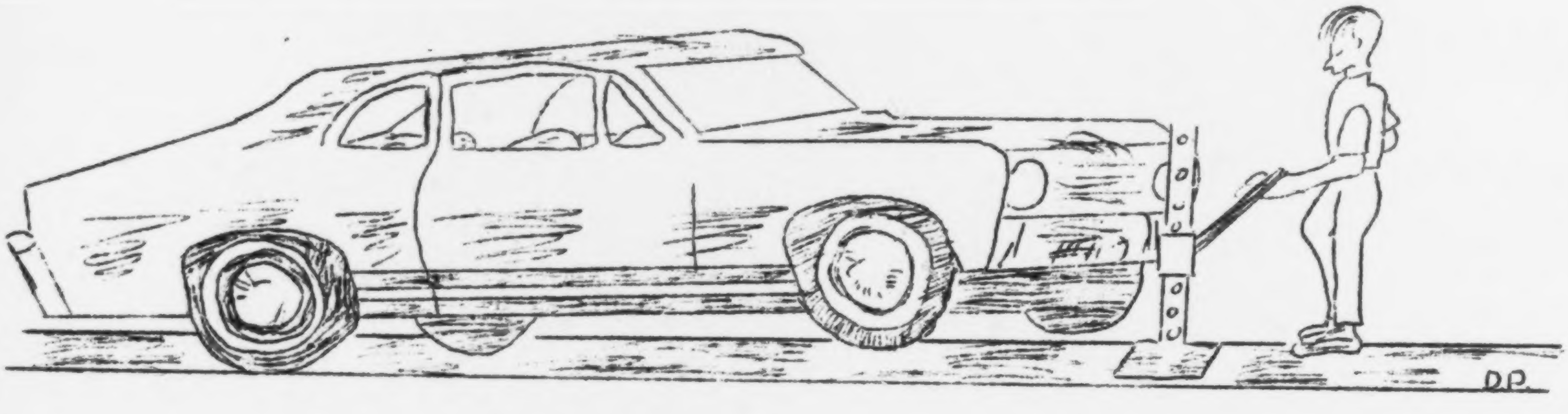


DP

P-16

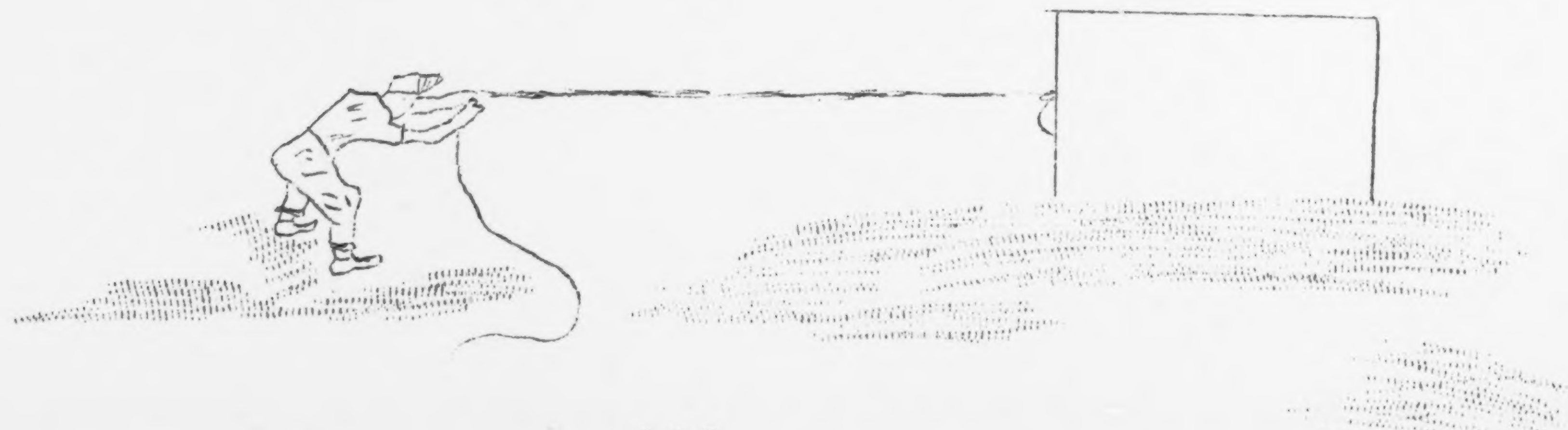
OBJECT *	DISTANCE height	RESISTANCE force	WORK ft.-oz.	LENGTH plane	EFFORT force	WORK ft.-oz.
Truck	1 Foot	4 Ounces		2 Feet		
Truck One weight	1 Foot	8 Ounces		2 Feet		
Truck Two weight	1 Foot			2 Feet		





P. 16

Observer Number	Force required to start the block moving	Force required to maintain a constant speed	Position of Block	Weight of Block
1			WIDE	
			NARROW	
2			WIDE	
			NARROW	
3			WIDE	
			NARROW	



P-17

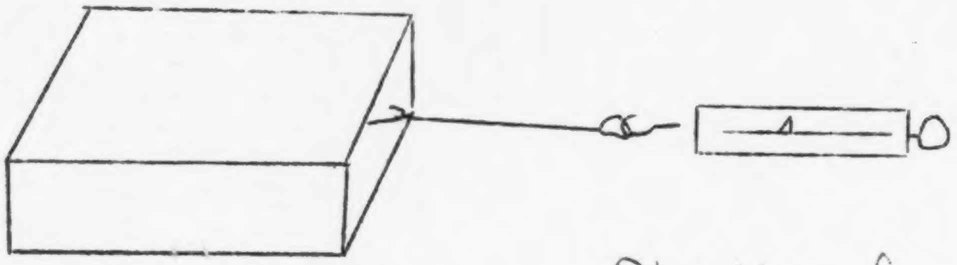
DATA ON THE EFFECT OF INCREASED WEIGHT ON FRICTION

Observer Number	Position of Block	Number of Blocks	Force required to start the block moving	Force required to maintain a constant speed
1	Wide side	1		
	Wide side	2		
2	Narrow side	1		
	Narrow side	2		
3	Wide side	2		
	Narrow side	2		

P-18

OBJECT	Position	Force		Why
		Table	Sand	Type of Friction
TRUCK	Rolling			
	On Its Side			
	Rolling & Weight			
YELLOW FRICTION BOARD	Smooth Side Down			
	Rough Side Down			
	Rough Side Down On Blue Rough Side			

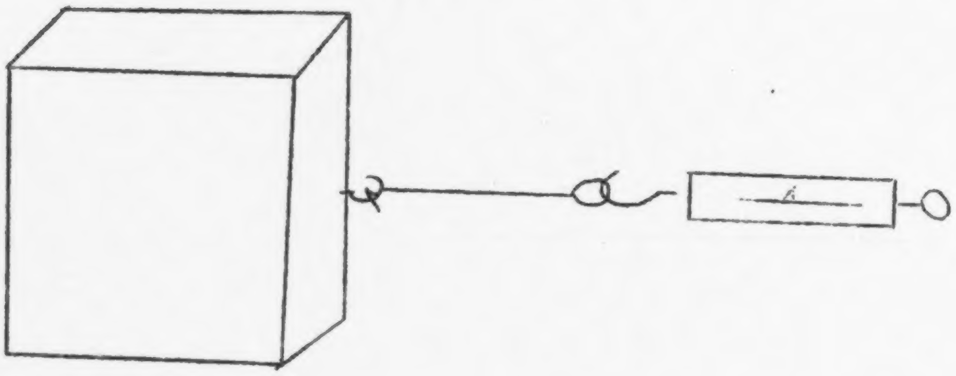
P-16, 17, 18



Starting force ________

Sliding force ________

Weight ______



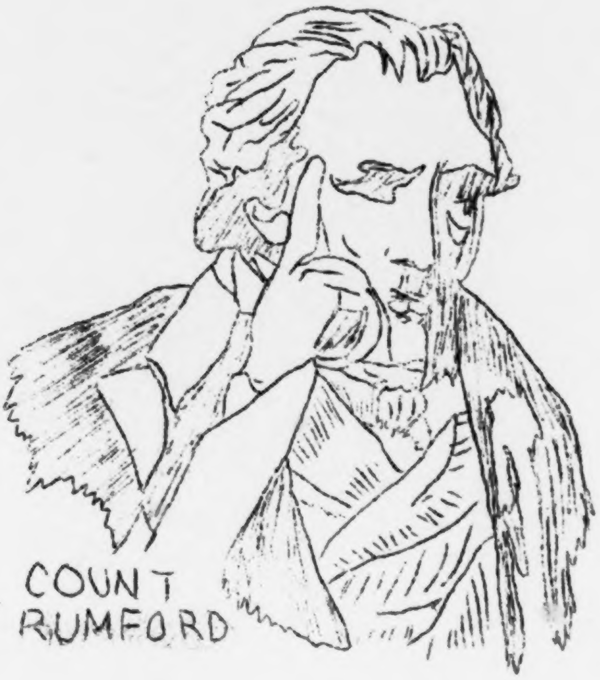
Starting force ______

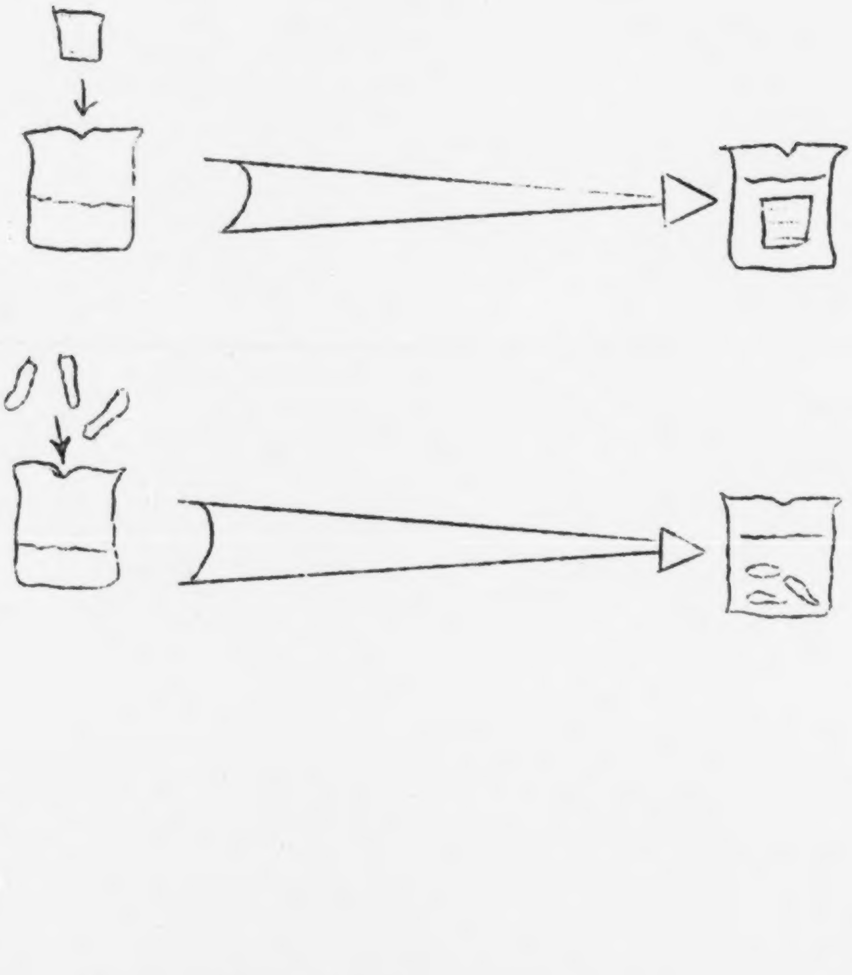
Sliding force ______

Weight ____

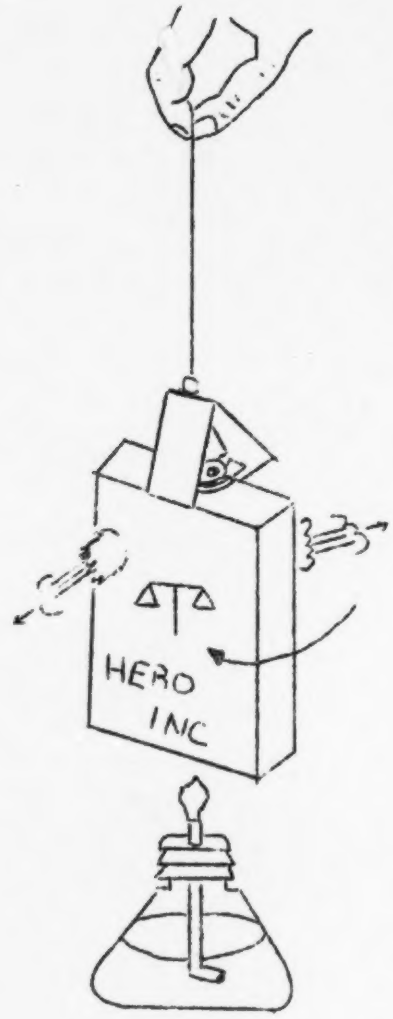
D.P.

P-21


COUNT
RUMFORD

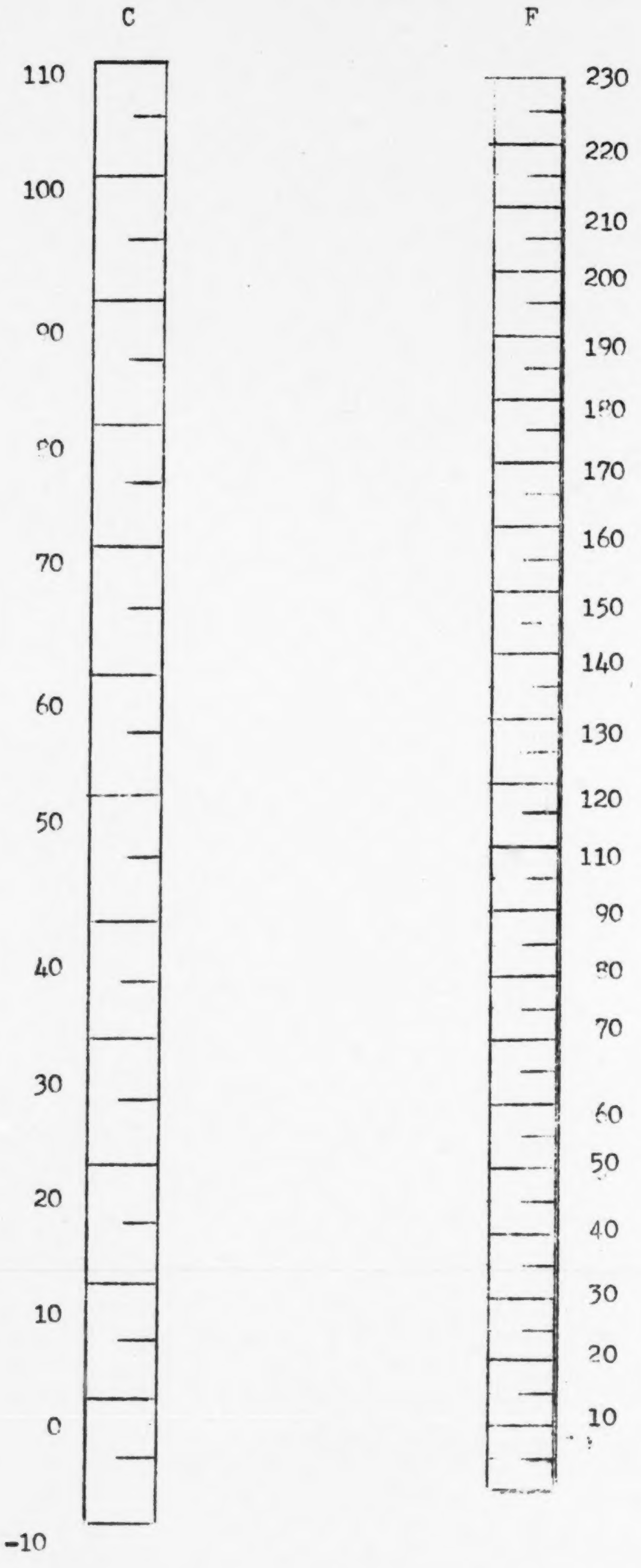


P-22



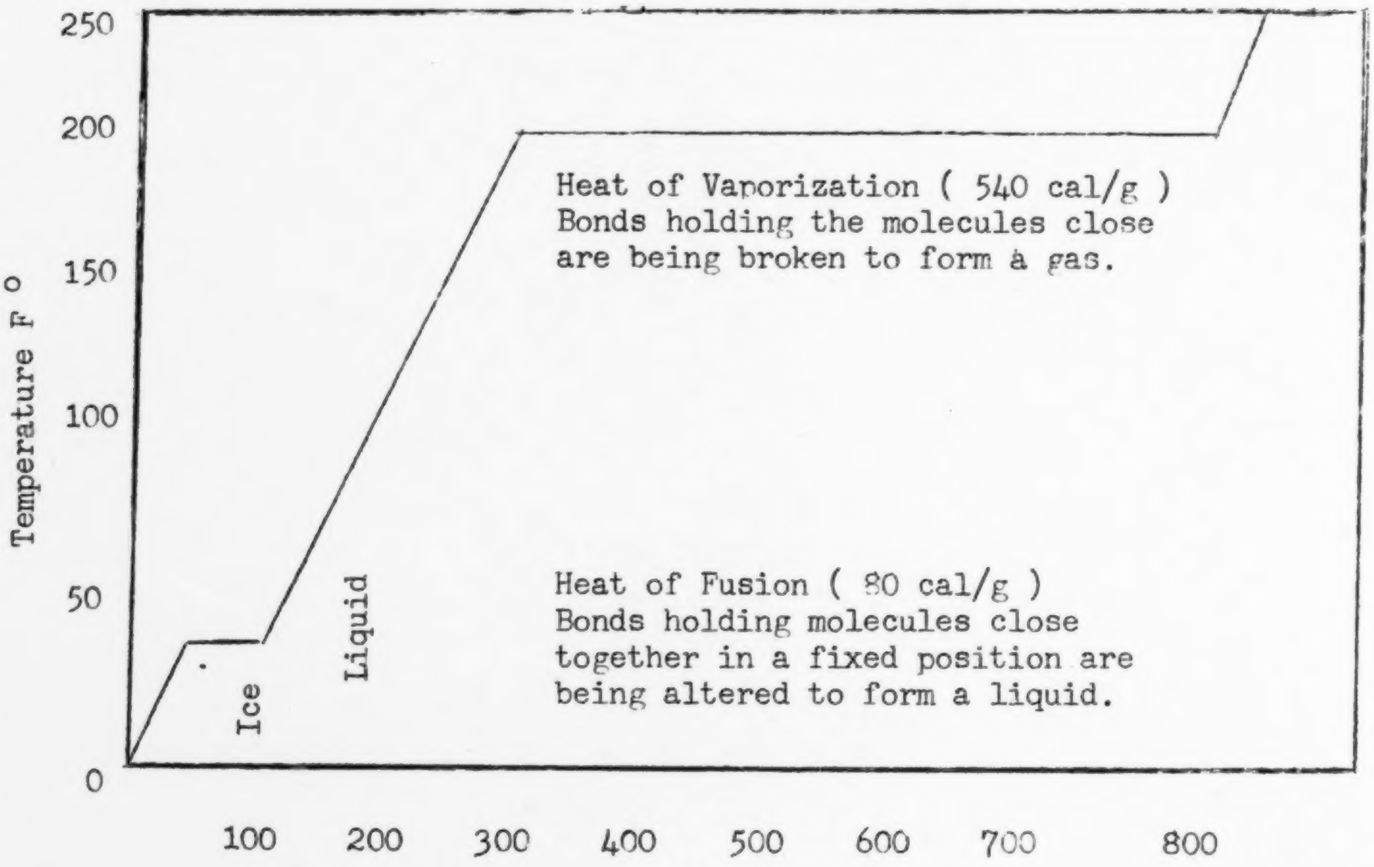
TIME	WAIT	4	6	8	10	12	14	16	18	20
REVOLUTION per minute	3 MINUTES									

P-23


C
-10
F

P-24

P-25

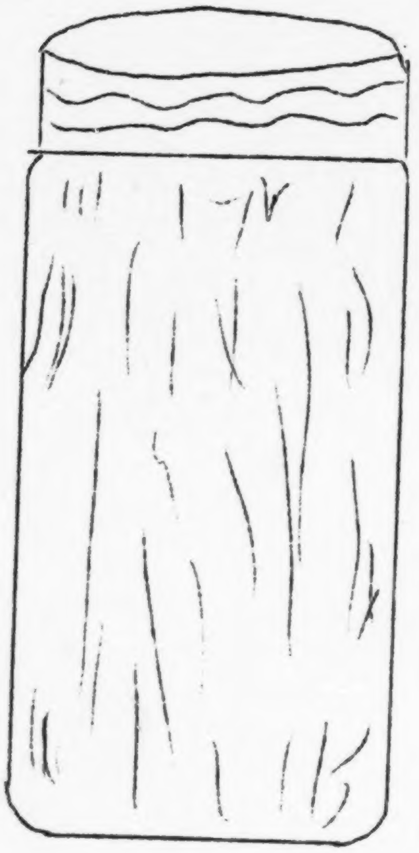


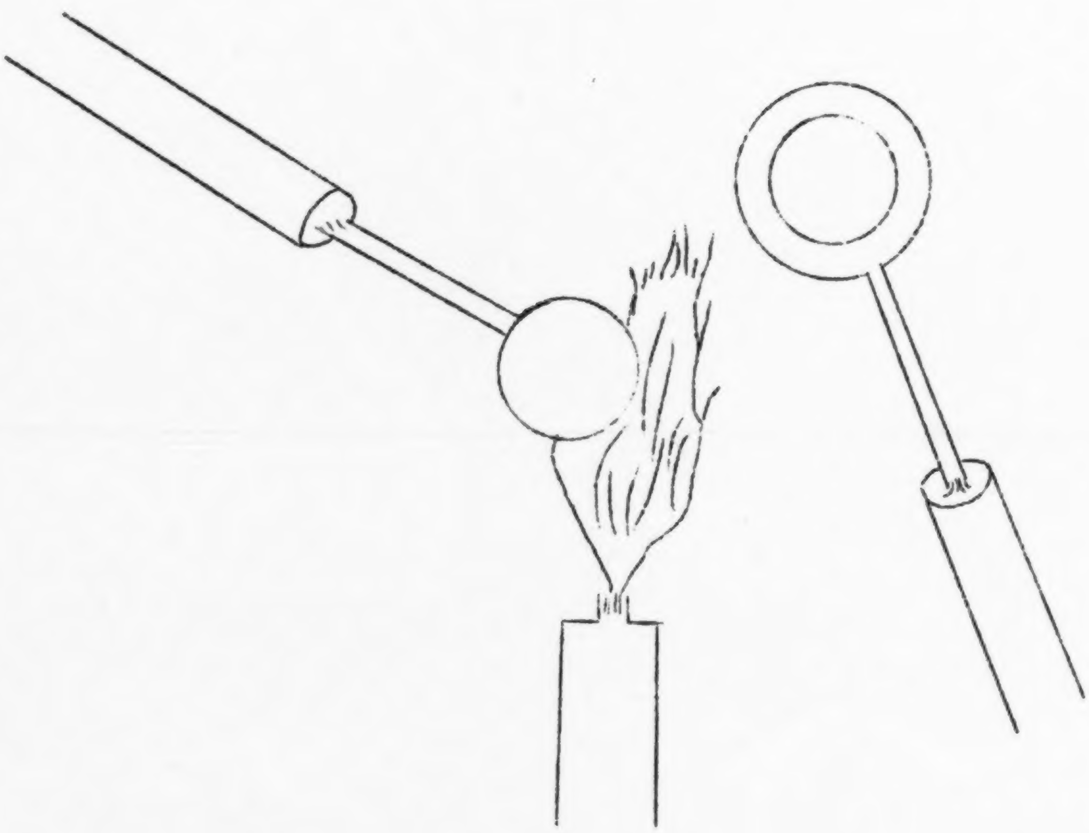
Change of State of Water

Heat of Vaporization (540 cal/g)
Bonds holding the molecules close
are being broken to form a gas.

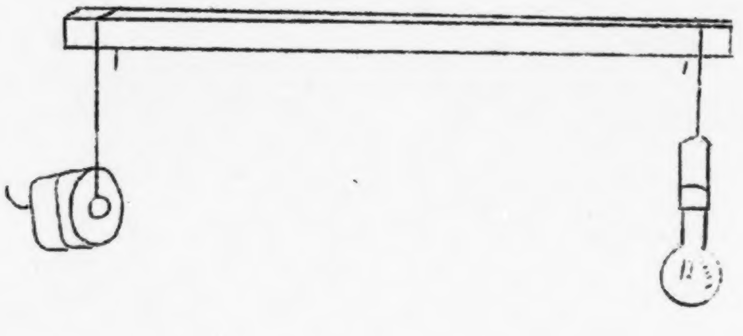
Heat of Fusion (80 cal/g)
Bonds holding molecules close
together in a fixed position are
being altered to form a liquid.

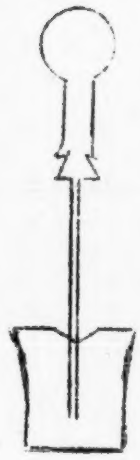
P-25A





P-26





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MINUTES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. NO ICE																				
2. WITH ICE